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Application of Air Pathway Analyses for Superfund Activities

NUS Corp., Gaithersburg, MD

Prepared for:

Environmental Protection Agency, Research Triangle Park, NC

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Abstract: The report is one in a series of manuals dealing with air pathway analysis at hazardous waste sites. The document was developed for the Office of Air Quality Planning and Standards in cooperation with the Office of Emergency and Remedial Response (Superfund). The document is an interim final manual offering technical guidance for use by a diverse audience including EPA Air and Superfund Regional and Headquarters staff, State air and Superfund program staff, Federal and State remedial and removal contractors, and potentially responsible parties in analyzing air pathways at hazardous waste sites. The manual provides for flexibility in tailoring the air pathway analysis to the specific conditions of each site.

PROCEDURES FOR CONDUCTING AIR PATHWAY ANALYSES FOR SUPERFUND APPLICATIONS

VOLUME I

APPLICATION OF AIR PATHWAY ANALYSES FOR SUPERFUND ACTIVITIES

INTERIM FINAL

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PREFACE

The

This is one in a series of manuals dealing with air pathway analysis at hazardous waste sites. This document was developed for the Office of Air Quality Planning and Standards in cooperation with the Office of Emergency and Remedial Response (Superfund). It has been reviewed by the National Technical Guidance Study Technical Advisory Committee and an expanded review group consisting of State agencies, various groups within the U.S. Environmental Protection Agency, and the private sector. This document is an interim final manual offering technical guidance for use by a diverse audience including EPA Air and Superfund Regional and Headquarters staff, State Air and Superfund program staff, Federal and State remedial and removal contractors, and potentially responsible parties in analyzing air pathways at hazardous waste sites. This manual is written to serve the needs of individuals having different levels of scientific training and experience in designing, conducting, and reviewing air pathway analyses. Because assumptions and judgments are required in many parts of the analysis, the individuals conducting air pathway analyses need a strong technical background in air emission measurements, modeling, and monitoring. Remedial Project Managers, On Scene Coordinators, and the Regional Air program staff, supported by the technical expertise of their contractors, will use this guide when establishing data quality objectives and the appropriate scientific approach to air pathway analysis. This manual provides for flexibility in tailoring the air pathway analysis to the specific conditions of each site, the relative risk posed by this and other pathways, and the program resource constraints.

Air pathway analyses cannot be reduced to simple "cookbook" procedures. Therefore, the manual is designed to be flexible, allowing use of professional judgment. The procedures set out in this manual are intended solely for technical guidance. These procedures are not intended, nor can they be relied upon, to create rights substantive or procedural, enforceable by any party in litigation with the United States.

It is envisioned that this manual will be periodically updated to incorporate new data and information on air pathway analysis procedures. The Agency reserves the right to act at variance with these procedures and to change them as new information and technical tools become available on air pathway analyses without formal public notice. The Agency will, however, attempt to make any revised or updated manual available to those who currently have a copy through the registration form included with the manual.

Copies of this report are available, as supplies permit, through the Library Services Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711 or from the National Technical Information Services, 5285 Port Royal Road, Springfield, Virginia 22161.

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SUPERFUND ABBREVIATIONS/ACRONYMS

ACGIH	American Conference of Government Industrial Hygienists
ACL	Alternate Concentration Limit
AO	Administrative Order on Consent
APA	Air Pathway Analysis
APCD	Air Pollution Control Device
ARAR	Applicable or Relevant and Appropriate Requirement (Cleanup Standard)
ATSDR	Agency for Toxic Substances and Disease Registry
CAA	Clean Air Act
CAS	Carbon Adsorption System
CD	Consent Decree
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CERI	Center for Environmental Research Information
CFR	Code of Federal Regulations
CR	Community Relations
CRF	Combustion Research Facility -- Pine Bluff, Arkansas
CWA	Clean Water Act
DQO	Data Quality Objective
DRE	Destruction and Removal Efficiency
EDD	Enforcement Decision Document
ERT	Environmental Response Team
ESP	Electrostatic Precipitator
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FP	Fine Particualte

FS	Feasibility Study
HRS	Hazard Ranking System
HSWA	Hazardous Waste Engineering Amendments to RCRA, 1984
HWERL	Hazardous Waste Engineering Research Laboratory
IDLH	Immediately Dangerous to Life or Health
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
NBAR	Non-binding Preliminary Allocation of Responsibility
NCP	National Contingency Plan
NEIC	National Enforcement Investigations Center
CFPA	National Fire Protection Association
NIOSH	National Institute of Occupational Safety and Health
NPL	National Priorities List
NRC	National Response Center
NRT	National Response Team
NTIS	National Technical Information Service
OERR	Office of Emergency and Remedial Response
O&M	Operation and Maintenance
ORD	Office of Research and Development
OSC	On-Scene Coordinator
OSH Act	Occupational Safety and Health Act
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Repsonse
OTA	Office of Technology Assessment
PA	Preliminary Assessment
PEL	Permissible Exposure Limits
PIC	Products of Incomplete Combustion

PM-20	Particualte Matter with Physical Diameter <20 um
PRP	Potentially Responsible Party
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RA	Remedial Action
RCRA	Resource Conversation and Recovery Act
RD	Remedial Design
REL	Recommended Exposure Limit
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPM	Remedial Project Manager
RRT	Regional Response Team
RQ	Reportable Quantity
SAB	Science Advisory Board
SARA	Superfund Amendments and Reauthorization Act
SCAP	Superfund Comprehensive Accomplishments Plan
SI	Site Inspection
SITE	Superfund Innovative Technology Evaluation
SWDA	Solid Waste Disposal Act (RCRA predecessor)
TLV	Threshold Limit Value
TLV-C	Threshold Limit Value - Ceiling
TLV-STEL	Threshold Limit Value - Short-Term Exposure Limit
TLV-TWA	Threshold Limit Value - Time-Weighted Average
TSDF	Treatment Storage and Disposal Facility
TSCA	Toxic Substances Control Act

TSP	Total Suspended Particulate
Title III	Emergency Planning and Community Right-To-Know Act (SARA)
T&E	Testing and Evaluation
UST	Underground Storage Tank
VO	Volatile Organics
VOC	Volatile Organic Compound

SECTION 1

INTRODUCTION

The multi-volume set of Procedures for Conducting Air Pathway Analyses for Superfund Applications has been developed by the U.S. Environmental Protection Agency (EPA) to address the potential for hazardous air emissions from Superfund sites. These emissions can occur at hazardous spill locations, undisturbed Superfund sites, as well as during site cleanups. Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the recent Superfund Amendments and Reauthorization Act (SARA), EPA has the responsibility for assessment and cleanup of Superfund sites. Although air emissions pose a potential human health risk at these sites, comprehensive national guidance does not exist for determining the magnitude and impact of these emissions.

An air pathway analysis is a systematic approach which involves the application of modeling and monitoring methods to estimate emission rates and concentrations of air contaminants. The goal of the multi-volume set is to provide recommended procedures for the conduct of air pathway analyses (APAs) which meet the needs of the Superfund program. This has been accomplished by identifying the application of APAs in the Superfund process, and by providing recommended procedures for conducting APAs for Superfund. The procedures are intended for use by EPA Remedial Project Managers (RPMs), Enforcement Project Managers (EPMs), and air experts as well as by EPA Superfund contractors. The procedures are also generally applicable to hazardous waste sites not included on the NPL.

The Procedures for Conducting Air Pathway Analyses for Superfund Applications consists of four volumes as follows:

- Volume I - Application of Air Pathway Analyses for Superfund Activities;

- Volume II - Estimation of Baseline Air Emissions at Superfund Sites;

- Volume III - Estimation of Air Emissions from Clean-up Activities at Superfund Sites; and

- Volume IV - Procedures for Dispersion Modeling and Air Monitoring for Superfund Air Pathway Analyses.

Volume I presents the critical information that an RPM or EPM will need to answer the following questions:

- What is an APA and why is it important? (Section 2 - Air Pathway Analyses Process Overview).

- What are the air emissions sources that should be evaluated at a Superfund site? (Section 3 - Superfund Air Emission Sources).

- How is an APA used within the Superfund process? (Section 4 - Applications of Air Pathway Analyses to Superfund).

- What is an appropriate source-specific APA approach? (Section 5 - Overall Procedures for Conducting Air Pathway Analyses for Superfund).

- Where can EPA air experts and contractors find additional technical procedures for implementing the selected APA approach? (Section 5 - which provides cross-references to Volumes II-IV).

The emphasis of Volume I is providing a recommended APA procedure for the remedial phase of the Federal Superfund process. The pre-remedial Superfund activities (e.g., National Priority List scoring) already have a structured screening approach (i.e., the Hazard Ranking System) which accounts for the air pathway. The procedures, especially Volume I, are intended to provide a consistent and technically adequate approach for the conduct of APAs for remedial phase activities (i.e., Remedial Investigations/Feasibility Studies, Records of Decision, Remedial Actions and Operation and Maintenance). The APA approaches discussed in Volume I are also generally applicable to removal activities (if planning time for the selection and conduct of an APA is allowed) as well as to remedial activities since the activities of both are similar except that removal activities operate under an accelerated schedule.

Volume I defines the general procedure for the conduct of APAs for Superfund and references appropriate sections within Volumes II-IV for detailed technical procedures regarding modeling and monitoring techniques (see Figure 1). Volumes II through IV present and discuss alternative modeling techniques and monitoring techniques for implementing the Superfund APA procedure presented in Volume I. Volume II (Radian, 1989a) presents procedures for developing baseline air emissions for uncontrolled Superfund sites, with an emphasis on landfills and lagoons. Volume III (Radian, 1989b) presents procedures for estimating air emission impacts from remedial activities. This volume includes emission estimation techniques for sources such as incinerators, air strippers, soil vapor extraction, and soil handling. Volume IV (NUS, 1989) presents procedures for dispersion modeling and air monitoring. The information in Volumes II, III, and IV will be primarily of interest to EPA air experts and Superfund contractors responsible for the conduct of APAs. However, the technical procedures provided in Volumes II-IV are not Superfund-activity specific. Therefore, Volumes II-IV will also be useful to state air staff responsible for supporting hazardous waste site cleanup projects.

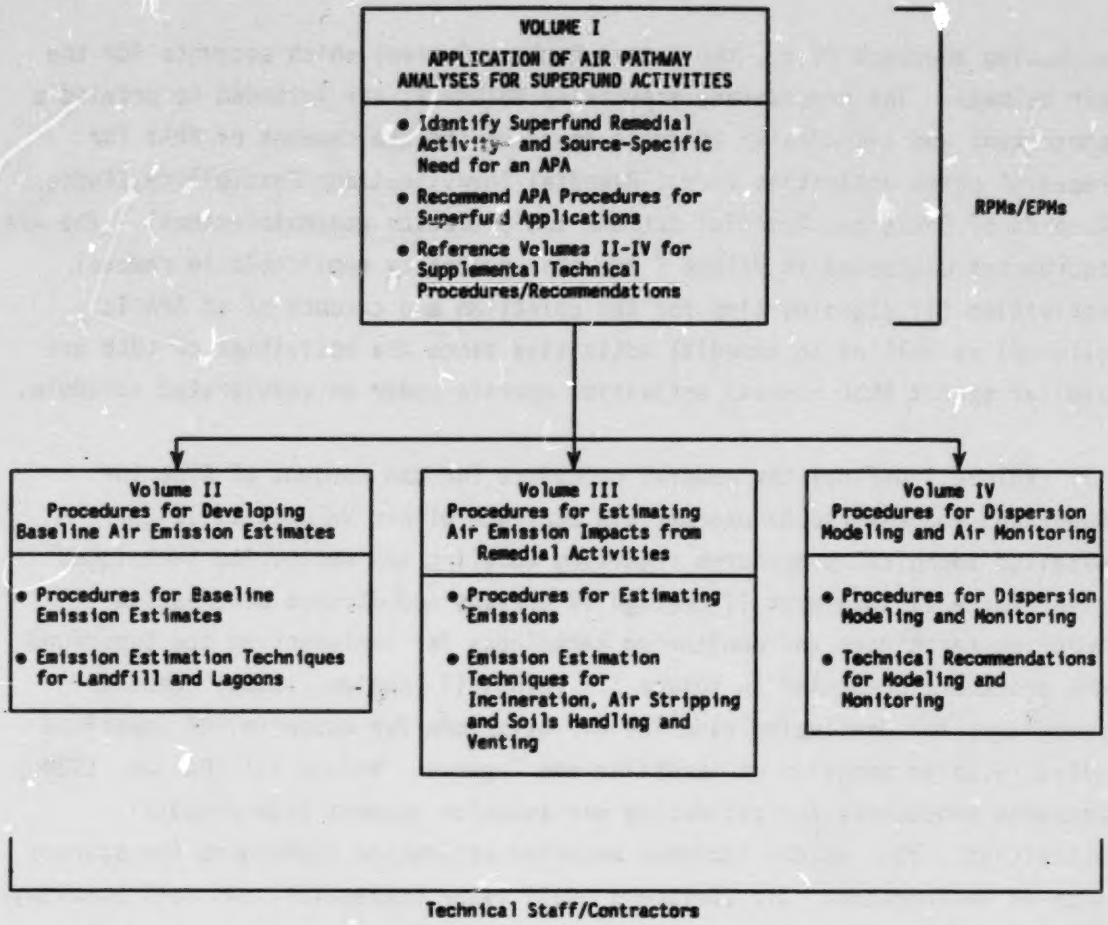

VOLUME I
APPLICATION OF AIR PATHWAY ANALYSES FOR SUPERFUND ACTIVITIES
• Identify Superfund Remedial Activity- and Source-Specific Need for an APA
• Recommend APA Procedures for Superfund Applications
• Reference Volumes II-IV for Supplemental Technical Procedures/Recommendations
RPMs/EPMs
Volume II
Procedures for Developing Baseline Air Emission Estimates
• Procedures for Baseline Emission Estimates
• Emission Estimation Techniques for Landfill and Lagoons
Volume III
Procedures for Estimating Air Emission Impacts from Remedial Activities
• Procedures for Estimating Emissions
• Emission Estimation Techniques for Incineration, Air Stripping and Soils Handling and Venting
Volume IV
Procedures for Dispersion Modeling and Air Monitoring
• Procedures for Dispersion Modeling and Monitoring
• Technical Recommendations for Modeling and Monitoring
Technical Staff/Contractors

Figure 1. Procedures for Conducting Air Pathway Analyses (APA) for Superfund Applications - Overview.

SECTION 2

AIR PATHWAY ANALYSES PROCESS OVERVIEW

2.1 OVERVIEW

It is imperative that a consistent definition of air pathway analyses be used for specifying and implementing the recommended procedures presented in this document. An air pathway analysis (APA) is a systematic approach involving a combination of modeling and monitoring methods to assess actual or potential receptor exposure to air contaminants. Therefore, an APA is an exposure assessment for the air pathway and it provides input to the Superfund risk assessment process. The primary components of an APA are:

- Characterization of air emission sources (e.g., estimation of contaminant emission rates);
- Determination of the effects of atmospheric processes (e.g., transport and dilution); and
- Evaluation of receptor exposure potential (i.e., what air contaminant concentrations are expected at receptors of interest for various exposure periods).

This section presents background information concerning air emission mechanisms, atmospheric processes, receptor exposure potential and alternative APA approaches. This information will provide an enhanced appreciation of the bases and components of the recommended Superfund APA procedure and supplementary technical procedures presented in Section 5.

2.2 AIR EMISSION MECHANISMS

Superfund air emissions may be classified as either point or area sources. Point sources include vents (e.g., landfill gas vents) and stacks (e.g., incinerator and air stripper releases), while area sources are generally associated with fugitive emissions (e.g., from landfills, lagoons and contaminated surface areas). A further identification and discussion of Superfund air contaminant sources is presented in Section 3.

Air contaminant emissions can be classified into two basic categories (i.e., gas phase emissions and particulate matter emissions). The emission mechanisms associated with gas phase and particulate matter releases are quite different. Discussions of these air emission mechanisms are presented in the following subsections.

A more detailed discussion of baseline air releases is presented in Section 2 of Volume II of this series, and discussion of clean-up air emissions is presented in Section 2 of Volume III.

2.2.1 Gas Phase Emissions

Gas phase emissions primarily involve organic compounds but may also include certain metals. Gaseous emissions from a Superfund site can be released through a variety of mechanisms, including:

- Volatilization;
- Biodegradation;
- Photodecomposition;
- Hydrolysis; and
- Combustion.

The importance of each of these mechanisms varies as a function of source type (see Table 1). The recognition of the significance of these mechanisms will facilitate the selection of appropriate remediation approaches.

TABLE 1. AIR EMISSION MECHANISMS - GAS PHASE EMISSIONS

	Volatilization	Biodegradation	Photo-decomposition	Hydrolysis	Combustion
Pre-Remediation Sources					
• Landfills	I	S	N	N	S
• Lagoons	I	I	S	S	N
• Contaminanted Soil Surfaces	I	I	N	N	N
• Open Containers (above-ground)	I	I	S	S	S
Remediation Sources					
• Soil Handling	I	N	N	N	N
• Air Stripper	I	N	N	N	N
• Incinerator	S	N	N	N	I
• Soil Vapor Extraction	I	N	N	N	N
• Solidification/ Stabilization	I	N	N	N	N
Post-Remediation Sources					
• Landfills	I	S	N	N	N
• Lagoons	I	I	S	S	N
• Soil Surfaces	I	I	N	N	N
• Open Containers (above-ground)	I	I	S	S	N

Key: I = Important
S = Secondary
N = Negligible or Not Applicable

Volatilization is typically the most important mechanism for air releases and occurs when molecules of a dissolved or pure substance escape to an adjacent gas layer. For wastes at the surface, this results in immediate transport into the bulk atmosphere. Volatilization from subsurface wastes results in a concentration gradient in the soil-gas from the waste to the surface. The rate of emissions is usually limited by the rate of diffusion of contaminants to the soil-air interface. Volatilization is thus an important process for the release of gaseous emissions from both surface contamination and contaminants in the shallow subsurface. The rate of volatilization of contaminants at a soil-air boundary is a function of the concentration and properties of the escaping chemical, soil properties (moisture, temperature, clay content, and organic content), and properties of the air at soil level (temperature, relative humidity, and wind speed). The rate of volatilization from liquid surfaces is dependent on the concentration of the contaminants in the boundary layer of liquid at the liquid-air interface. Any factors that enhance mixing in the bulk liquid and replenishment of contaminants in the boundary layer, will enhance the volatilization rate. It is important to note that "volatile" and "semi-volatile" are broad categories and further subdivision by vapor pressure, toxicity, etc. may be necessary to properly evaluate air emissions.

Several processes can act to reduce the concentration of a given contaminant and thereby diminish its overall rate of emissions. Biodegradation takes place when microbes break down organic compounds via metabolic processes. Biodegradation may be an important mechanism for gas-phase emissions (and waste treatment) from wastes in the upper layers of the soil or ponds. The rate of organic compound decomposition depends on the structure of the compound, the metabolic requirements of the microbes, and the amount of moisture, oxygen, and nutrients available to the microbes. Photodecomposition occurs when a hazardous chemical absorbs light and reacts, or when the chemical reacts because of light absorption by surrounding elements. Hydrolysis occurs when a chemical reacts with water. For organic compounds, the reaction usually replaces a functional group with a hydroxyl.

Combustion, the process of burning, can be a source of both particulates and volatile compounds (EPA, 1987b).

2.2.2 Particulate Emissions

Particulate matter emissions from a Superfund site can be released through wind erosion, mechanical disturbances, and combustion. Hazardous substances, such as metals, can also be adsorbed onto particulate matter and thereby transported with the inert material. The importance of each of these mechanisms varies as a function of source type (see Table 2). The hazardous constituents of concern in a particulate release may involve constituents that are either absorbed or adsorbed onto the particulate, or constituents that actually comprise the particulate. These may include volatile and semi-volatile organic compounds, metals, and non-volatile toxic organic compounds.

Significant atmospheric dust can arise from the disturbance of soil exposed to the air. Dust generated from these area sources is referred to as "fugitive" because it is not discharged to the atmosphere in a confined flow stream. The dust generation process is caused by two basic physical phenomena: entrainment of dust particles by the action of wind erosion of an exposed surface under moderate-to-high wind speeds; and pulverization and abrasion of surface materials by mechanical disturbances (EPA, 1985a).

For airborne particulates, the particle size distribution plays an important role in inhalation exposure. Large particles tend to settle out of the air more rapidly than small particles, but may be important in terms of non-inhalation exposure. Very small particles (i.e., those that are less than 2.5 to 10 microns in diameter) are considered to be respirable and thus present a greater health hazard than the larger particles.

TABLE 2. AIR EMISSION MECHANISMS - PARTICULATE EMISSIONS

	Wind Erosion	Mechanical Disturbances	Combustion	Adsorption
Pre-Remediation Sources				
• Landfills	I	I	N	S
• Lagoons	S	S	N	S
• Contaminanted Soil Surfaces	I	I	N	I
• Containers (above-ground)	N	I	N	N
Remediation Sources				
• Soil Handling	I	I	N	S
• Air Strippers	N	N	N	S
• Incinerators	N	N	S	S
• Soil Vapor Extraction	N	N	N	S
• Solidification/ Stabilization	I	I	N	S
Post-Remediation Sources				
• Landfills	I	I	N	S
• Lagoons	S	S	N	S
• Soil Surfaces	I	I	N	I
• Containers (above-ground)	N	I	N	N

Key: I = Important
S = Secondary
N = Negligible or Not Applicable

2.3 ATMOSPHERIC PROCESSES

The atmosphere is recognized as a major potential exposure pathway for the migration of releases from Superfund sites. Unlike other environmental media, the air pathway is characterized by short migration times, relatively large exposure areas, and a virtual inability to mitigate the potential consequences of a release after the contaminant enters the atmosphere. The fundamental atmospheric processes affecting airborne contaminants include atmospheric transport and diffusion as well as transformation, deposition, and depletion. The extent to which these atmospheric processes act on the contaminant determines the magnitude, composition, and duration of the release, the route of human exposure, and the impact of the release on the environment. Subsurface gas migration is another pathway which can result in exposure to air contaminants from some Superfund sources (e.g., landfills, underground tanks). Further discussions of the major atmospheric processes are presented in the following subsections.

2.3.1 Transport and Diffusion

Once released to the ambient air, a contaminant is subject to simultaneous transport and diffusion processes in the atmosphere. Atmospheric transport/diffusion conditions are significantly affected by meteorological, topographic and source factors.

The contaminant will be carried by the ambient air, following the spatial and temporal characteristics of the wind flow field (as determined by wind direction and speed conditions). The turbulent motions of the atmosphere (as characterized by atmospheric stability conditions) promote diffusion of airborne gases and particulate matter. Thus, the local meteorology during and after the release determines where the contaminant moves and how it is diluted in the atmosphere.

Terrain features can dramatically alter the transport and diffusion experienced by a contaminant between its source and receptors. Complex terrain features such as valleys, hills and mountains can significantly affect transport conditions and diffusion rates. The rate of diffusion will also depend on whether the site is located in an urban, rural or coastal setting.

Source factors such as release height and source configuration influence the transport and diffusion of air releases. In addition, atmospheric releases involving denser-than-air gases will behave differently than neutrally buoyant materials.

2.3.2 Transformation, Deposition and Depletion

Contaminants emitted to the atmosphere are subjected to a variety of physical and chemical influences. Transformation processes can result in the formation of more hazardous substances, or, on the other hand, may result in hazardous constituents being converted into less harmful ones. A variety of inorganic and organic materials may be present along with the natural components of the air. The emissions may remain in the atmosphere for a considerable time and undergo a myriad of reactions. Both primary and secondary products are exposed to further changes through oxidation and photochemical reactions (Randerson, 1984). In general, however, these effects are secondary to transport and diffusion in importance, and are subject to more uncertainty.

Airborne contaminants can become depleted from the atmosphere by the natural cleansing processes of wet deposition and dry deposition. Wet deposition involves the incorporation of toxic pollutants into the various forms of precipitation, and the subsequent deposition of the effluent onto the ground, vegetation, and/or structures. Dry deposition proceeds without the aid of precipitation and denotes the direct collection of gaseous and particulate species on land or water surfaces. Gravitational settling also plays an important role in the deposition of particulate matter (especially particles of greater than 30 microns in the vicinity of the source).

Although deposition depletes concentrations of the contaminant in air, it increases the concentration of contaminants on vegetation and in soils and water bodies. In addition, deposited contaminants are subject to some degree of resuspension, particularly through wind erosion and wind speeds which exceed 10-15 mph.

2.4 RECEPTOR EXPOSURE POTENTIAL

The primary modes of exposure to toxic contaminants released to the atmosphere are direct inhalation, ingestion of vegetation that is contaminated as a result of deposition of particles, ingestion of contaminated milk and meat products from animals eating contaminated crops, and dermal contact.

The direct inhalation of airborne contaminants is the primary mode of exposure from the toxic pollutant air pathway. Inhalation brings chemicals into contact with the lung. Most inhaled chemicals are gases or vapors of volatile liquids. Absorption in the lung is usually high because the surface area is large, and blood vessels are close to the exposed surface area.

Chemicals may also be inhaled in solid or liquid form as dusts or aerosols. The absorption of solid particulate matter is highly dependent upon the size and chemical nature of the particles (Government Institutes, 1986). The EPA has indicated that particles less than 10 microns in diameter are small enough to penetrate to the thoracic region of the body.

The dose to an individual from breathing contaminated air is dependent upon the individual's ventilation rate (i.e., the rate of inhaled air), body weight, retention fraction, and the toxic air pollution concentration.

Atmospheric deposition of contaminants onto feed crops and use of contaminated water (due to deposition) to irrigate feed crops can also result in the ingestion of contaminated crops by animals. In addition, contaminated water can be used as part of the animals' drinking-water supply. Human exposure to contaminants can then result from subsequent ingestion of contaminated animal products.

Uptake of contaminants can also result from dermal contact with soil contaminated from atmospheric deposition. Soil contact includes both ingestion from hand-to-mouth contact or absorption through the skin (Whelan, 1987).

2.5 AIR PATHWAY ANALYSES APPROACHES

The following basic approaches are available for the conduct of APAs:

- Modeling
  - Emission rates
  - Atmospheric dispersion; and
- Monitoring
  - Emission rates
  - Air concentrations.

Emission modeling as well as emission monitoring can be used to characterize source emission rates. Dispersion modeling is the primary approach to characterize atmospheric processes and predict concentrations, and air monitoring can be used to directly measure air concentrations at receptor locations. However, there are numerous alternative modeling/monitoring approaches that may be viable for site-specific APA applications.

Air emission models can be used to estimate constituent-specific emission rates based on waste/source input data for many types of Superfund sources. (An emission rate is defined as the source release rate for the air pathway in terms of mass per unit time.) The models are based upon theoretical considerations and have been evaluated against pilot-scale and field test results. Often, the models are empirically correlated. However, because the models attempt to predict complex physical and chemical phenomena, they are uncertain and should be used carefully. These models can be particularly useful when monitoring is impractical (e.g., when health-based criteria levels are lower than the detection levels of a monitoring approach).

Source monitoring is an alternative approach to determine emission rates for existing sources. Direct emission sampling may be used for point sources such as vents and stacks. An isolation flux chamber (see Reference 5) may be used for area source emission measurements. On-site air monitoring (particularly near the emission source) is an alternative approach for characterizing area source emissions if direct emission monitoring is not practical (e.g., considering equipment availability and detection limits).

Atmospheric dispersion models can be used to estimate constituent-specific concentrations at receptor locations of interest based on input emission rate and meteorological input data. Atmospheric dispersion models can also be used for monitoring program design applications to identify areas of high concentration relative to actual receptor locations of interest. High concentration areas which correspond to actual receptors are priority locations for air monitoring stations. Frequently, it may not be practical to place air monitoring stations at actual off-site receptor locations. However, it may be useful to characterize concentrations at these locations to support a health and environmental assessment. In these cases, dispersion patterns based on modeling results can be used to extrapolate monitored concentrations to off-site receptor locations.

Confirmatory air monitoring may also be appropriate to characterize air concentrations for receptor locations of interest. However, this approach is limited to existing sources, and monitoring methods or detection levels commensurate with health criteria may not be available for all contaminants of interest.

Procedures for the selection of appropriate modeling versus monitoring approaches for source-specific APA applications are provided in Section 5 of this document. Additional technical discussions regarding the implementation of modeling and monitoring APAs are presented in Volumes II through IV.

SECTION 3

SUPERFUND AIR EMISSION SOURCES

3.1 OVERVIEW

Superfund sites are potential sources of air emissions that can impact onsite/offsite health and safety. Therefore, it is important to identify site-specific air emission sources and conduct follow-up air pathway analyses to characterize the potential impacts. Superfund air emission sources can be classified into three stages as follows:

- Pre-remediation sources;
- Remediation sources; and
- Post-remediation sources

Pre-remediation sources are Superfund sites that have not been cleaned up, such as landfills, lagoons, contaminated soil surfaces and above-ground containers (e.g., tanks and drums).

Remediation sources represent the disturbed site conditions during the cleanup process. Usually, these sources have a higher air emission potential than the undisturbed site. Remediation air emission sources include soil handling operations (e.g., excavation), air strippers, onsite incinerators, soil vapor extraction (in-situ venting), and solidification/stabilization processes.

Post-remediation sources can include the same types of air emission sources found at uncontrolled sites (i.e., landfills, lagoons, contaminated surface soils, and above-ground containers). However, air emission rates are expected to be lower at the post-remediation stage compared to earlier stages.

Superfund sites have the potential for gaseous and particulate emissions before, during, and after clean-up. A summary of potential emission rates from these sources is presented in Tables 3, 4, and 5 for pre-remediation sources, remediation sources, and post-remediation sources, respectively. Brief discussions of each of these sources are presented in this section. Landtreatment data are included in the tables, as they are indicative of emissions from highly contaminated surface soils. Comprehensive discussion of the emission potential for Superfund air emission sources are presented in Section 2 of Volume II and Section 2 of Volume III.

3.2 PRE-REMEDIATION SOURCES

3.2.1 Landfills

A landfill is generally an excavated area or natural depression used for waste disposal. Several methods of landfill construction exist, including the trench, area, and ramp methods. Each method uses different techniques for waste placement, compaction and cover. However, many landfills will lack adequate records of waste placement techniques of waste characteristics, and with few technological controls, such as liners or cover systems, that would prevent escape of waste or waste constituents to the environment. For this reason, air emissions from uncontrolled landfills are primarily area source emissions that occur through a variety of mechanisms.

There are two primary area sources of gaseous emissions from landfills: (1) lateral and vertical diffusion of volatile organic compounds through the overburden or landfill cover; and (2) exposure of contaminated soils and waste through water and wind erosion of cover material with subsequent evaporation and/or sublimation of exposed liquids or solids. The short-term rate of volatile emissions through the first mechanism, diffusion through the landfill overburden or cover, is proportional to the volatility and areal extent of the emission source. All other factors being equal, if the contaminant source is highly volatile (expressed as a high vapor pressure or high Henry's Law constant), volatile emissions will occur at a high rate. Likewise, if there

TABLE 3. TYPICAL EMISSION RATES BY POLLUTANT CLASS: UNCONTROLLED SOURCES (RADIAN 1989a, RADIAN 1989b, EPA 1987b)

	Pollutant Class	Emission Rates (kg/day, Unless Otherwise Noted)
Landfills	Volatile and semi-volatile organics	4.18×10^{-5} - 1.06×10^{-3} kg/m^{2}day
	Particulates	Not available.
Lagoons	Volatile and semi-volatile organics	6.19×10^{-5} kg/m^{2}day
	Particulates	Not significant
Contaminanted Soil Surfaces:		
• Land treatment	Volatile and semi-volatile organics	Not available
	Particulates	Not available
• Waste piles	Volatile and semi-volatile organics	Not available
	Particulates	1.62×10^{-5} - 6.25×10^{-5} kg/m^{2}day
Above-ground Containers		
• Tanks	Volatile and semi-volatile organics	11.54
	Particulates	Not significant
• Container storage areas	Volatile and semi-volatile organics	0.066
	Particulates	Not significant

TABLE 4. TYPICAL EMISSION RATES BY POLLUTANT CLASS: REMEDIATION SOURCES (RADIAN 1989a, RADIAN 1989b, EPA 1987b)

	Pollutant Class	Emission Rates (kg/day, Unless Otherwise Noted)
Soil Handling	Volatile and semi-volatile organics	Not available
	Particulates	27.08 - 168.2
Air Strippers	Volatile and semi-volatile organics	0.05 - 2.5
	Particulates	Not significant
Incinerators*	Volatile and semi-volatile organics	3.82×10^{-7} - 8.1×10^{-3}
	Particulate matter/ metals	1.5 - 69
	NO_x	1.14×10^{-7} - 4.57×10^{-5}
	HF	9.92×10^{-8} - 9.92×10^{-7}
	HCl	4.52×10^{-7} - 4.52×10^{-5}
	SO_2	1.59×10^{-7} - 1.90×10^{-4}
In-situ venting	Volatile and semi-volatile organics (uncontrolled emissions)	1-110 kg/day per recovery well
	Volatile and semi-volatile organics (controlled emissions)	0.01 - 5.5. kg/day per recovery well
Solidification/ Stabilization	Volatile and semi-volatile organics	Not available
	Particulates	124 - 164

* Assume 95% efficiency for pollution control device.

TABLE 5. TYPICAL EMISSION RATES BY POLLUTANT CLASS: UNCONTROLLED SOURCES (RADIAN 1989a, RADIAN 1989b, EPA 1987b)

	Pollutant Class	Emission Rates (kg/day, Unless Otherwise Noted)
Landfills	Volatile and semi-volatile organics	1.30×10^{-5} - 2.16×10^{-4} kg/m^{2}day
	Particulates	Not available.
Lagoons	Volatile and semi-volatile organics	1.30×10^{-5} - 9.07×10^{-4} kg/m^{2}day
	Particulates	Not significant
Contaminanted Soil Surfaces:		
• Land treatment	Volatile and semi-volatile organics	8.78×10^{-4} - 0.014 kg/m^{2}day
	Particulates	Not available
• Waste piles	Volatile and semi-volatile organics	Not available
	Particulates	1.95×10^{-4} - 7.5×10^{-4} kg/m^{2}day
Above-ground Containers		
• Tanks	Volatile and semi-volatile organics	11.54
	Particulates	Not significant
• Container storage areas	Volatile and semi-volatile organics	0.066
	Particulates	Not significant

is widespread soil or ground-water contamination, diffusion of volatile organics through the overburden will occur more rapidly than if the contaminant source is confined to a smaller area. The rate of gas generation within the landfill also affects the rate of volatile emissions. Generation of inorganic gases (e.g., CO_2) within the landfill is possible, especially at sites with municipal wastes, and the movement of the inorganic gases can carry along organic compounds and enhance the latter's emission rates.

The second non-point source of gaseous emissions--exposure of contaminated soils and waste through erosion, with subsequent evaporation and/or sublimation of exposed liquids and solids--is dependent on both the construction and maintenance of the landfill cover system, and on factors that influence erosion, such as rainfall rates and wind patterns. Emissions are likely to be lowest at landfills that have periodic cover inspection and maintenance procedures, since erosion of these landfill covers would likely be repaired before significant emissions could occur. However, uncontrolled landfills rarely have regular cover inspection and maintenance systems in place, so the likelihood of emissions through this pathway at uncontrolled landfills is high, particularly in climates conducive to erosion.

The most significant point source of gaseous emissions from landfills is active gas venting system emissions. Active gas venting systems employ either vacuum or positive pressure pumping to extract gases from landfill soils. The extent of emissions from this source depends on the presence and/or efficiency of the emission control device at the gas collection source. Commonly used emission control devices are condensers, carbon adsorption filters, and incinerators. However, uncontrolled landfills are not likely to have emission control devices in place on their gas venting systems.

3.2.2 Lagoons

A lagoon, generally referred to for regulatory purposes as a surface impoundment, is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials designed to hold an accumulation of liquid wastes, or wastes containing some liquids. The discussion also applies to any free liquid at Superfund sites.

The primary source of air emissions from lagoons or surface impoundments is emissions of volatile and semi-volatile organics from the free liquid surface. Uncontrolled Superfund sites are not likely to have mechanisms in place (e.g., temporary covers) to control emissions from the liquid surface, making this a significant air emissions pathway. As seen in Tables 3 and 5, emissions from lagoons can be roughly equivalent to emissions from landfills. Since lagoons are usually smaller in area, the emission rate per given area is much higher than for landfills. Air emissions occur through evaporation, and generation of aerosols through wave action. The degree of emissions through evaporation is also affected by the volatility and solubility of the liquid in the impoundment, and by environmental factors such as temperature, atmospheric pressure, and wind speed. Wind speed also affects generation of aerosols through wave action.

At sites where there has been subsurface contamination of soils or ground water through overtopping or leaks, a second, less important, source of volatile and semi-volatile emissions is lateral and vertical diffusion of contaminants through the surrounding soil. Significant air emissions through this pathway are most likely at lagoons without natural or synthetic liners, or where the bottom of the lagoon is at or near the water table. The extent of emissions from this pathway also depends on the areal extent and chemical nature (i.e., volatility) of the contaminants in the subsurface, and on the physical properties of the soil (porosity, density, and moisture content) surrounding the impoundment.

A final potential source of contaminant emissions from lagoons is wind erosion of contaminated soils and solid residues from dry areas of the impoundments or impoundment berms. Generally, however, this is not a significant source of particulate emissions.

3.2.3 Contaminated Soil Surfaces

Soil contamination and subsequent gaseous and particulate air emissions can occur through a variety of mechanisms, including breaching of above-ground tanks and containers, overtopping of surface impoundments, subsurface seepage of leachate from buried waste, and spills occurring through careless waste handling practices. Wind transport of aerosols may occur during waste application; volatilization may occur after waste application; and erosion of contaminated soils may occur at any time. All of these air release mechanisms are affected by meteorological factors such as temperature, precipitation, wind speed, and barometric pressure.

Depending on their configuration with respect to prevailing winds, and depending on whether a liner is present, waste piles can also be significant sources of soil contamination and subsequent air emissions. Waste pile controls that may reduce wind erosion and entrainment of particulates include windscreens and other enclosures; construction of piles with their length perpendicular to the prevailing winds; use of foams or other coverings; and use of dust suppressants.

In the case of spills or leaks from above-ground tanks and containers, the highest potential for releases of volatile and semi-volatile organics occurs immediately after the release or spill. The rate and amount of emissions will depend on the size of the spill, the chemical and physical properties of the spilled material, and atmospheric conditions. After the spill, migration of contaminants through the soil and in the ground water can provide a long-term source of volatile emissions. The rate of transfer of subsurface gases to the atmosphere by this mechanism is dependent on the physical properties of the soil matrix (porosity, density, and moisture content) and on climatic conditions, including rainfall, temperature, barometric pressure, and wind speeds. Frequently, the emitting surface becomes depleted of contaminants and acts as a barrier to inhibit further emissions. When the surface is disturbed during remediation, the emission rate may then increase substantially.

Transport of particulates and contaminated soils can occur through wind erosion, which has the potential to disperse contaminants and provide a long-term, area-wide source of air emissions. The potential for wind erosion depends on atmospheric conditions such as temperature, rainfall, and wind speed, and on the physical state of the waste.

3.2.4 Containers

The extent of emissions from above-ground containers and tanks depends on the age and structural integrity of the container or tank and the physical state and chemical characteristics of the waste it contains. In the event of a spill, the extent of air emissions depends on waste volume and characteristics, and on environmental conditions such as direction of prevailing wind and wind speed.

The primary source of emissions from open, above-ground tanks and containers is through volatilization from the free liquid surface. Sublimation of solids from open tanks or containers is generally a minor source of volatile and semi-volatile emissions. Depending on the amount and the nature of the wastes contained in closed tanks and containers, regular venting may also be a source of volatile and semi-volatile emissions, especially if the tank is filled and emptied.

Tanks and containers that are old, or that have been subject to unusual or repeated chemical and mechanical stresses, are more likely than new tanks to lose their structural integrity and release contaminants to the environment. Massive container failures provide an immediate source of volatile emissions to the atmosphere from the spill area, and will generally contaminate surface and subsurface soils and ground water. Subsurface contamination provides a long-term source of contamination via lateral and vertical diffusion of subsurface gas through the overburden.

In addition to the potential for gaseous emissions, contaminated surface soils and particulate wastes exposed through spills may be transported from the site via wind erosion. The potential for wind erosion of particulates is highest in areas of dry soils and high average wind speeds. Otherwise, the potential is low. Once transported away from the site, particulates provide a long-term source of air emissions.

3.3 REMEDIATION SOURCES

3.3.1 Soil Handling

Remedial action at almost any Superfund site will involve soil excavation, transportation, dumping, storage, or grading. The soil may also have to be screened to remove rocks, trees, drums, etc. prior to undergoing treatment. All of these operations have the potential to cause particulate emissions and waste volatilization.

A potential point source of volatile emissions from remedial soil handling operations is through breaching the integrity of buried tanks and drums through excavation operations. The potential for volatile emissions through this mechanism increases at uncontrolled disposal sites where records of the location of buried tanks and drums have not been maintained. Enhanced emissions of volatile and semi-volatile organics may also occur through removal of overburden, exposing volatile wastes, and through facility soil handling operations such as grading, dumping, and transportation.

All of these operations have the potential to cause particulate emissions as well as volatile emissions. Generally, once contaminated soil is excavated, it is transported by truck to storage piles. Emissions of contaminated soil particles and solid wastes will occur at all phases of soil handling operations. Their magnitude will depend on wind and weather conditions, particle size and mass, soil type, and the amount of vehicular traffic at the site, size and activity of waste piles, the presence or absence of covers on trucks and piles, and the extent of onsite contamination. Once particulate emissions are mobilized through these mechanisms, which may transport them away from the site, where they have the potential for intermedia transfer through surface water runoff or ground-water infiltration.

3.3.2 Air Strippers

In air stripping, a counter-current flow of air and contaminated water is used to strip volatile organic contaminants from water. Specified water and air flow rates, tower configurations, and residence times are used to maximize transfer of volatile organics from the liquid phase to the gas phase.

The primary source of volatile and semi-volatile emissions from air stripping is the air stripper exhaust. In the absence of a pollution control device, the extent of volatile emissions from this source will depend on the concentration of volatiles in the contaminated water, the Henry's law constant of the contaminants, water temperature, air temperature, air/water contact time, and air/water ratio. If an emission control device, such as a condenser or a carbon adsorption filter, is present on the air stripping tower, the extent of volatile emissions will depend on its efficiency.

Other potential sources of air emissions from air stripping include holding or treatment tanks where contaminated water is in direct contact with air, and fugitive emissions from connecting valves, pumps, and pipes. The magnitude of volatile emissions from open holding tanks is dependent upon the concentration of volatile organics in the water, volatility of the contaminants, surface area of the exposed water, degree of agitation of the water surface, and the residence time of water in the tank. In general, fugitive volatile emissions from closed sources such as pipes and valves are not significant since the wastewater they contain is relatively dilute.

Since air stripping is a treatment method for contaminated water (primarily contaminated ground water), particulate emissions are not a concern with air stripping. However, drilling of wells designed to collect contaminated ground water have a small potential for mobilization of contaminated soil particles. Ground-water recovery wells are also a potential, although minor, source of volatile emissions.

3.3.3 Thermal Treatment

The most common type of thermal treatment is incineration,and the following discussion primarily relates to incineration. However, emerging technologies such as low temperature thermal stripping also have significant potential for emissions of organic compounds.

Incineration is a process that uses controlled combustion to oxidize materials to less toxic products, and to significantly reduce waste volume. It requires maintenance of excess oxygen in the combustion chamber to ensure complete combustion of organic materials to CO_2, H_2O, SO_x, NO_x, HCl, HBr, and HF. Emission control devices are commonly used on incinerators to reduce emissions of acid gases, particulates, and other materials. The incinerator types most commonly used for hazardous waste destruction are rotary kiln, multiple hearth, fluidized bed, and liquid injection.

The largest point source of both volatile and particulate emissions from incinerators is stack exhaust. Incinerator stack exhaust generally contains carbon monoxide, particulates, metals, nitrogen oxides, acid gases such as SOX, HCl, HBr, and HF, products of incomplete combustion, and the fraction of waste not combusted at all. Waste characteristics observed to affect incinerator emissions include the physical state of the waste, moisture content, particle size, thermal content, and chemical composition. Likewise, operating characteristics such as waste feed rate, temperature, residence time, excess air rate, facility size and type, atomization, and control device efficiency also affect stack emissions.

Since metals are not destroyed in incinerators, they are released as a component of stack gas, remain in the ash, or are removed in any control devices present. Depending on their chemical characteristics, they are either volatilized in the combustion chamber or remain in the solid phase. Volatile metals such as mercury, selenium, antimony, cadmium, and lead tend to leave the incinerator in the stack gas (as vapor) or condense onto particles in the stack gas stream, while less volatile metals such as nickel and chromium tend to remain in the incinerator bottom ash.

Particulate emissions may originate from the waste feed, the auxiliary fuel, or the combustion air. The extent of particulate emissions is strongly affected by waste and fuel compositions, incinerator type and operation, and effectiveness of air pollution control devices. Particulate emissions consist of inorganic salts and metals that either pass through the system as solids or vaporize in the combustion chamber and recondense as solid particles in the stack gas. High molecular weight hydrocarbons may also contribute to particulate emissions through self-nucleation, dehydration by inorganics, and adsorption onto inorganic oxides.

Formation of nitrogen oxides (NO_x) tends to increase with combustion temperature. Excess air and high heat releases also contribute to NO_x formation. Emissions of SO_x, HCl, HF, and HBr, depend on the sulfur, chlorine, fluorine, and bromine content of the waste and fuel feeds, and the efficiency of the pollution control device.

Fugitive emissions from incinerator operations can be a significant source of air emissions, and are sometimes more significant than stack emissions. Fugitive emissions occur through leaking valve and pump fittings, flanges, storage tanks, sampling and instrument connections, and handling and transfer operations. Fugitive emissions can be minimized through proper design and operation and periodic inspections of incinerator facilities. Fugitive emissions from collecting, transporting, and storing the waste prior to incineration may also be significant and must be considered.

3.3.4 Soil Vapor Extraction

Two systems exist to control the movement of subsurface gases: active aeration (vacuum or positive pressure pumping) and passive venting. Active aeration systems use positive pressure or vacuum pumping to bring gases to the surface or divert them away from critical structures. Passive venting systems allow natural pressure gradients to bring gases to the surface where they are dispersed in the atmosphere.

Vacuum pumping systems use a series of vapor recovery wells, similar in construction to ground-water monitoring wells, from which vapors are extracted using a vacuum pump. Once extracted and collected, the vapors are usually condensed and treated by methods such as carbon adsorption or incineration. Sources of volatile emissions from vacuum pumping include inadequate well surface seals, and emissions from the pollution control device designed to treat the recovered gas.

Positive pressure pumping is not a gas collection technology, but rather a method to divert subsurface gas from a critical area or structure. It involves injecting pressurized air into the ground to laterally displace the subsurface gas. However, vertical as well as lateral displacement can occur, causing gases to diffuse through overlying soils to the atmospheres. Passive aeration systems make use of natural pressure gradients created through temperature fluctuations, barometric changes, wind, and rainfall to slowly move subsurface gases to the surface. If the concentration of volatiles in the subsurface is significant, and the surface area over which they are released to the air is small, passive gas venting systems can be a significant source of volatile air emissions. Environmental factors such as gravity, pressure, temperature, wind, and rainfall; and soil parameters such as porosity, density, and moisture content are more important in passive rather than active gas venting systems.

3.3.5 Solidification/Stabilization

Solidification and stabilization processes are designed to reduce the hazard potential of a waste by converting it to its least soluble, mobile, or toxic form. The most commonly used solidification/stabilization techniques are Portland cementation and pozzolanic cementation, but other techniques include thermoplastic micro-encapsulation, organic polymer binding, and in-situ vitrification.

The two most commonly used solidification/stabilization techniques involve mixing a waste slurry with either Portland cement or a pozzolanic material such as fly ash, cement kiln dust, lime kiln dust, or hydrated lime. The resulting material has a low permeability, high structural integrity, and improved resistance to leaching. The potential for air emissions from this final material is very low. However, several steps in the solidification/stabilization process are potential sources of volatile and particulate air emissions.

These steps include loading wastes into the mixing bin, adding the solidification material, mixing together the waste and solidification material (sometimes with the addition of heat), removing the material from the mixing bin, and replacing material at the site after processing. Both volatile and particulate emissions are possible at each step in this process, depending on waste characteristics, soil type and percent of moisture, and the effectiveness of any emission control practices being used. The mixing step is generally the most important in terms of air emissions, and may account for 90+% of the emissions from stabilization. Common emission control practices for solidification/stabilization techniques are enclosure of the waste mixing area and apparatus, storage pile controls for raw materials, and enclosure of the binder preparation area. In the absence of these controls, air emissions depend on the volatile organic content of the waste particle size of the soil or waste; meteorological conditions such as wind speed, direction of prevailing winds, and amount of precipitation; and site activities such as excavation, dumping, and storage in piles.

3.4 POST-REMEDIATION SOURCES

3.4.1 Post-Rememdiation Sources - Landfills

Air emission sources for landfills after remediation are similar to those for landfills before remediation, with several important differences. Area sources of gaseous and particulate emissions are likely to be less significant after remediation. For example, post-remediation landfills are not likely to have high-level soil or ground-water contamination, which can be a significant source of volatile emissions at uncontrolled landfills. Also, diffusion of volatiles through the landfill cover is less likely after remediation, since gas recovery and collection systems are more likely to be in place, as well as better covers. Erosion of the cover and volatilization of the waste is a less significant air emissions pathway at post-remediation landfills, since the cover is more likely to be inspected and maintained regularly.

3.4.2 Post-Remediation Sources - Lagoons

The primary air emissions sources from post-remediation lagoons is volatilization of organics and aerosol formation from the free liquid surface. Emissions from this source are likely to be significant unless control techniques such as foams or temporary covers are in place. As with pre-remediation lagoons, emissions from the free liquid surface are higher at well-mixed lagoons, and at lagoons containing highly volatile waste. Emissions from lagoons are also affected by environmental factors such as temperature, atmospheric pressure, and wind speed.

Lateral and vertical diffusion of contaminants through the overburden is not a significant source of air emissions at a lagoon unless there is widespread soil or ground-water contamination. At post-remediation lagoons that have been recently constructed or retrofitted to meet minimum technology standards, soil or ground-water contamination is not likely, making the likelihood of emissions from this pathway very low.

As with unremediated lagoons, a potential source of emissions from lagoons after remediation is wind erosion of contaminated soils and solid residues from dry impoundments or impoundment berms. However, with proper design and operation controls in place, this is not a significant air emissions source.

3.4.3 Post-Remediation Sources - Soil Surfaces

The extent of volatile and particulate emissions from any post-remediation waste piles will depend on whether the pile is enclosed, and on whether erosion control mechanisms, such as wind screens, dust suppressants, and foams or other coverings are in place.

Removal and/or treatment of contaminated soils will occur during site remediation, so emissions from contaminated soil surfaces and diffusion of contaminants from the soil surface to the ground water are not expected to be a problem at post-remediation sites.

3.4.4 Post-Remediation Sources - Containers

The primary source of emissions from tanks and containers is volatilization from the free liquid surface. Sublimation of solids is generally only a minor source of volatile emissions. Remediation will typically involve emptying tanks and containers and removal of any unsound structures, so volatile emissions arising from leaks or ruptures are less likely.

SECTION 4

APPLICATION OF AIR PATHWAY ANALYSES TO SUPERFUND

4.1 OVERVIEW

This section provides background information that identifies various air pathway analysis (APA) applications within the Superfund program. Recommended procedures that define a step-by-step process to conduct these Superfund APAs are provided in Section 5.

Air pathway analyses are applicable to every activity in the Superfund process (as illustrated in Figure 2). In the pre-remedial phase of Superfund (Preliminary Assessments, Site Inspections, and Hazard Ranking System scoring) this involves data-gathering activities to assess potential and observed air releases (in the 1988 revisions to the HRS) and to provide input to a determination on whether the site is to be placed on the National Priorities List (NPL). However, EPA has already developed various technical procedures and guidelines which discuss characterization of the air pathway for pre-remedial Superfund activities. Therefore, the emphasis within this section is to identify appropriate APA applications for Superfund remediation and removal activities including planned removal activities, as well as post-remedial activities.

Superfund APAs have the following functional applications:

- Input to the selection of remedial technology/action.
- Input to the preparation and implementation of health and safety plans to protect onsite workers from potential air emissions.
- Input to the conduct of risk assessments as well as to the preparation and implementation of emergency contingency plans to protect the offsite population from potential air emissions.

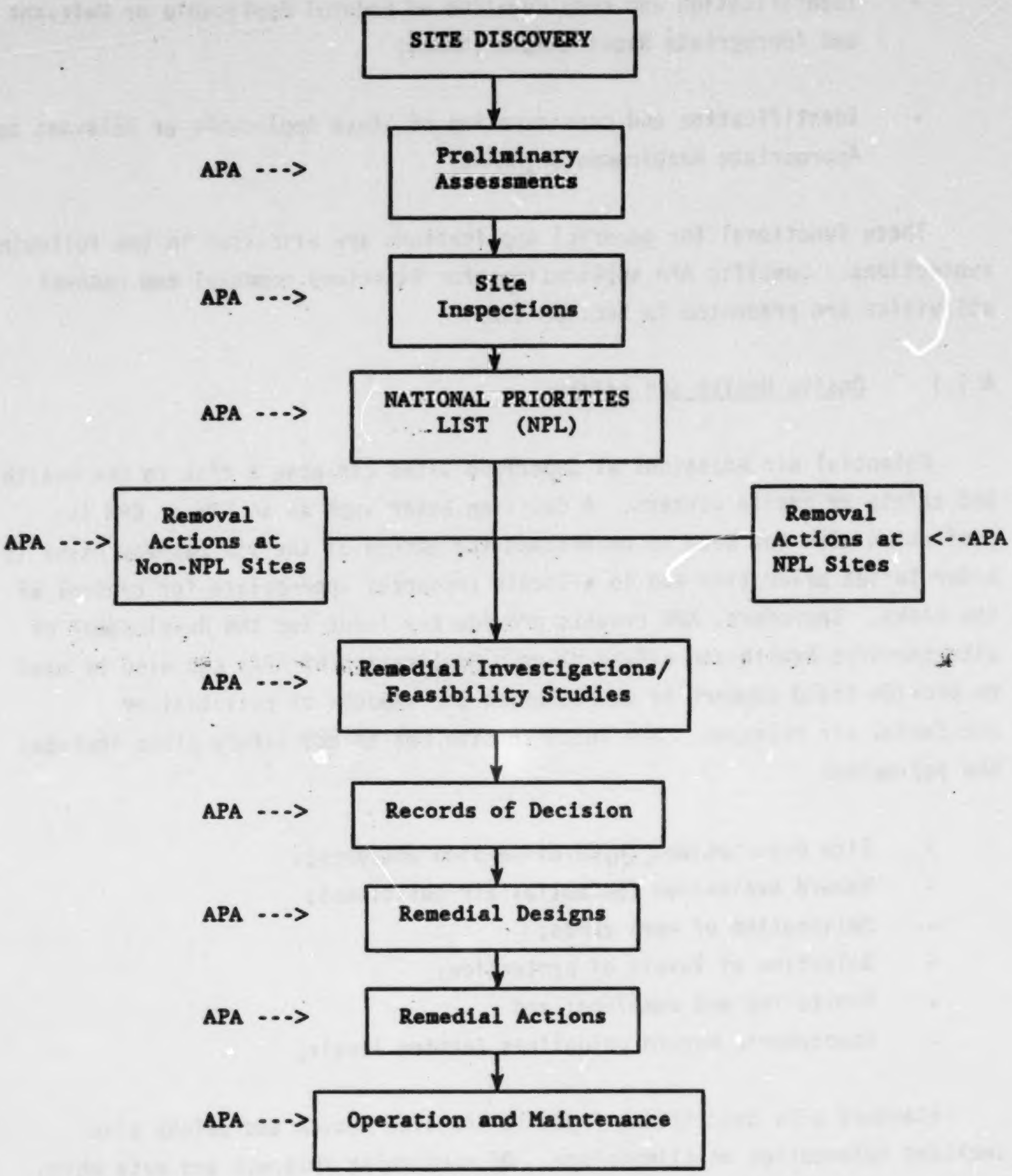

SITE DISCOVERY
APA --->
Preliminary Assessments
APA --->
Site Inspections
APA --->
NATIONAL PRIORITIES LIST (NPL)
APA --->
Removal Actions at Non-NPL Sites
Removal Actions at NPL Sites
<--APA
APA --->
Remedial Investigations/ Feasibility Studies
APA --->
Records of Decision
APA --->
Remedial Designs
APA --->
Remedial Actions
APA --->
Operation and Maintenance

Figure 2. **Superfund Air Pathway Analyses (APAs) Activity-Specific Applications - Overview.**

- Identification and consideration of Federal Applicable or Relevant and Appropriate Requirements (ARARs).

- Identification and consideration of State Applicable or Relevant and Appropriate Requirements (ARARs).

These functional (or generic) applications are discussed in the following subsections. Specific APA applications for Superfund remedial and removal activities are presented in Section 4.2.

4.1.1 Onsite Health and Safety

Potential air emissions at Superfund sites can pose a risk to the health and safety of onsite workers. A decision maker such as an RPM or EPM is confronted with the need to understand the nature of the air pathway risks in order to set priorities and to allocate resources appropriate for control of the risks. Therefore, APA results provide key input for the development of site-specific health and safety plans. Application of APAs can also be used to provide field support to characterize the impacts of potential or accidental air releases. APA input to site health and safety plans includes the following:

- Site descriptions (wind/dispersion patterns);
- Hazard evaluation (potential air emissions);
- Delineation of work zones;
- Selection of levels of protection;
- Monitoring and sampling; and
- Atmospheric hazard guidelines (action levels).

Standard site description input to the site health and safety plan includes information on climatology. Of particular interest are data which can be used to characterize local wind and dispersion conditions. This may involve obtaining available meteorological summaries from a representative National Weather Service station or the conduct of an onsite meteorological monitoring program. These meteorological data provide the basis to assess onsite air pathway hazards and to develop an appropriate health and safety plan.

Hazard evaluation involves identifying potential air emission sources at a Superfund site and estimating associated potential health and safety impacts. Therefore, monitoring and/or modeling may be necessary to characterize onsite air concentrations and onsite worker exposure potential. The hazard evaluation takes into account baseline air concentrations at the site as well as concentrations from the disturbed site (i.e., during remediation). When evaluating emission data, it is important to consider the time frame over which emissions take place. Therefore, it may be necessary to examine the hazards from both short-term peak emissions and long-term average emissions.

Delineation of work zones is a primary component of the site health and safety plan. The work zones are used to prevent or reduce the migration of contamination. Therefore air pathway exposure factors are an important consideration in the site-specific delineation of these zones.

Air emission rate modeling, dispersion modeling, emission rate monitoring, and/or air monitoring can provide a technical basis to define potential air pathway exposures for baseline and disturbed site conditions. These potential air pathway exposure conditions are considered when specifying the work zones. In addition, the command post and other support facilities in the Support Zone should be located upwind of the contaminated area.

Personnel must wear protective equipment when response activities involve known or suspected atmospheric contamination; when vapors, gases, or particulates may be generated; or when direct contact with skin-affecting substances may occur.

Selection of levels of protection involves considering air pathway exposure potential. Modeling and/or monitoring can be used to estimate these potential exposures.

To verify that site control procedures are preventing the spread of contamination at a Superfund site, a monitoring and sampling program is generally established. This routinely involves using direct-reading instruments and/or collecting air samples for particulate, gas, or vapor analyses.

Atmospheric hazard guidelines (i.e., action levels) are established within the site health and safety plan. These action levels provide a basis to safeguard onsite workers at Superfund sites. If air monitoring results exceed ambient criteria, then protective action procedures are triggered.

Additional Superfund program guidance regarding air pathway considerations for site health and safety plans is provided in the following documents:

- US EPA, November 1984. Standard Operating Safety Guides, Memorandum from William Hedeman, Jr.
- US EPA, October 1985. Occupational Safety and Health Guidance Manual for Hazardous Waste Sites Activities, Developed by NIOSH/OSHANSCG/EPA.
- OSHA, December 1986, Interim Final Rule for Hazardous Operations and Emergency Response, 29 CFR 1910.120.
- US EPA, December 1987. A Compendium of Superfund Field Operations Methods.

4.1.2 OffSite Health and Safety

Potential air emissions from Superfund sites can also pose a risk to the health and safety of people offsite. These potential off-site impacts are an integral component of the Superfund risk assessment process and should be considered in evaluating baseline air emission from the undisturbed Superfund site as well as from remediation activities. The need for air pathway exposure potential estimates is addressed in the following Superfund documents:

- US EPA, January 1986 draft, Superfund Exposure Assessment Manual
- US EPA, August 1986, The Endangerment Assessment Handbook
- US EPA, October 1986, Superfund Public Health Evaluation Manual.

The potential offsite impacts of Superfund air emissions are also addressed in Federal and State Applicable or Relevant and Appropriate Requirements (discussed in Section 4.1.3).

For sites that have the potential for accidental air emission events, the RPM/EPM should consider the application of air monitoring/modeling techniques during site disturbance operations (i.e., exploration and remediation) which have the potential for accidental air emission events. This approach (which actually is an extended application of the onsite health and safety plan) facilitates the early detection of these unplanned releases, estimation of onsite/offsite impacts, and provides input for community emergency prepardeness representatives.

Another important role of Superfund APAs is to support EPA community relations efforts. This is especially appropriate for sites which are perceived by the local community to have potentially unacceptable air impacts. The conduct of air monitoring/modeling studies can be used to provide early warnings of actual releases. Also, the results of these air studies provide a better basis to communicate the potential air pathway exposure potential to the public and demonstrate EPA's responsiveness to the community's concerns.

4.1.3 Applicable or Relevant and Appropriate Requirements (ARARs)

Superfund cleanup actions include consideration of compliance with ARARs of other environmental statutes as required by CERCLA Section 121. Federal and State ARARs include numerous complex provisions which frequently necessitate the conduct of modeling studies and/or monitoring programs. ARARs are critical to the evaluation of the air pathway, and EPA regional offices need to quickly make ARARs determinations for a given site. These ARARs may also limit air emissions and ambient concentrations at a Superfund site. Thus, compliance with ARARs will directly affect the selection and design of site-specific remedial/removal approaches including the application of control technology, as well as affecting the design of compliance monitoring during remediation. Compliance with ARARs will therefore affect the project schedule and costs. Therefore, RPMs and EPMs should identify site-specific ARARs during one of the initial tasks for a Superfund activity.

Sources of potential air pathway ARARs are summarized in Table 6. These combinations of Federal and State ARARs involve numerous regulations which vary as a function of source type. Federal ARARs that have been identified for Superfund air emission sources include the following:

- Clean Air Act
- Resource Conservation and Recovery Act
- Occupational Safety and Health Act
- Toxic Substances Control Act
- Federal Insecticide, Fungicide, and Rodenticide Act
- Atomic Energy Act
- Uranium Mill Tailings Radiation Control Act.

The Clean Air Act is a complex law that is the basis for numerous regulations that are potential ARARs for Superfund sites. Similarly, there are several evolving regulations associated with the Resource Conservation and Recovery Act.

TABLE 6. SOURCES OF POTENTIAL SUPERFUND ARARs

	Pre-Remediation Sources				Remediation Sources					Post Remediation Sources			
	Landfills	Lagoons	Contaminated Soil	Containers (Above-ground)	Soil Handling	Air Strippers	Incinerators	In-Situ Venting	Solidification/ Stabilization	Landfills	Lagoons	Soil Surfaces	Container (above ground)
FEDERAL Clean Air Act													
NAAQS:													
PM-10	X		X		X		X					X	X
SO_2							X						
CO							X						
O_3	X	X	X	X	X	X	X	X		X	X		X
NO_x							X						
Pb			X		X		X						
NESHAP:													
Asbestos	X		X	X	X					X		X	X
Benzene				X									X
NSPS:													
VOC													X
PSD:													
Ambient Impact							X						
BACT							X						
NA: Emission Off-sets							X						
LAER							X						
RCRA													
40 CFR 264	X		X		X				X	X		X	
3004d	X	X	X	X						X	X	X	X
3004n				X									X
3004o	X	X	X	X						X	X	X	X

(Continued)

TABLE 6. (Continued)

	Pre-Remediation Sources				Remediation Sources					Post Remediation Sources			
	Landfills	Lagoons	Contaminated Soil	Containers (Above-ground)	Soil Handling	Air Strippers	Incinerators	In-Situ Venting	Solidification/ Stabiliation	Landfills	Lagoons	Soil Surfaces	Container (above ground)
3004u	X	X	X	X						X	X	X	X
Subpart O							X						
OSHA	X	X	X	X	X	X	X	X	X	X	X	X	X
TSCA							X						
FIFRA	X	X	X	X	X		X		X	X	X	X	X
AEA	X	X	X	X	X				X	X	X	X	X
UMTRCA			X		X							X	
STATE Air Toxics Program:	X	X	X	X	X	X	X	X	X	X	X	X	X
SIP:	X	X	X	X	X	X	X	X	X	X	X	X	X
Odor/Fugitive Dust Nuisances:	X	X	X	X	X	X	X	X	X	X	X	X	X
HWR - Air Emissions:	X	X	X	X	X	X	X	X	X	X	X	X	X

Key:
PM-10 - Particulate matter less than 10 microns.
SO_2 - Sulfur dioxide
NA - Non-attainment
CO - Carbon monoxide
O_3 - Ozone
NO_2 - Nitrogen dioxide
VOC - Volatile Organic Compounds
TSCA - Toxic Substances Control Act
BACT - Best Available Control Technology
LAER - Lowest Achievable Emission Rate
NAAQS - National Ambient Air Quality Standards
NESHAP - National Emission Standards for Hazardous Air Pollutants
FIFRA - Federal Insecticide, Fungicide, and Rodenticide Act
NSPS - New Source Performance Standards
PSD - Prevention of Significant Deterioration
RCRA - Resource Conservation and Recovery Act
RCRA 40CFR264 - Fugitive Particulate Emissions
RCRA 3004^d - No Migration
RCRA 3004^o - Location Standards
RCRA 3004^n - Air Emissions Monitoring/Control
RCRA 3004^u - Corrective Action
RCRA Subpart O - Hazardous Waste Incinerators
AEA - Atomic Energy Act
SIP - Site Implementation Plan for Clean Air Act
OSHA - Occupational Safety and Health Act
UMTRCA - Uranium Mill Tailings Radiation Control Act

CERCLA Section 121(d)(2)(A) specifically limits the scope of State ARARs to those that are promulgated and more stringent than Federal requirements. In the case of State environmental programs which have been authorized by EPA to be fully administered and enforced in lieu of the Federal program, the stringency of the State requirements has already been established (i.e., the State program must be at least as stringent, such that it provides for compliance with the requirements of the Federal Act). A summary of principal potential State ARARs which address the air pathway is presented in Table 6.

A number of State and local air pollution control agencies have adopted or are in the process of establishing programs to regulate what are generally referred to as "toxic air pollutants." These programs differ from State to State in the pollutants and sources regulated and the safe levels adopted.

Many states control toxic air pollutants through imposition of best available control technology and then determine whether residual emissions exceed State standards. Other States control toxic air pollutants through acceptable ambient concentrations. In this process, the concentration of the toxic pollutant is estimated by modeling to a receptor, usually at the fenceline of the source, and compared with the acceptable limit. the definition of an "acceptable limit" varies widely from State to State. Many States establish acceptable limits by applying a safety or uncertainty factor to occupational standards (e.g., threshold limit values [TLVs]). These factors vary from 1/10 to 1/420.

Other States regulate carcinogens using risk assessment principles. For example, the risk to the most exposed individual in any population exposed to a carcinogen (for an assumed 70-year lifetime) cannot exceed 1 x 10-5. A typical State air toxics program will require a source to do the following:

- Identify pollutants of concern by comparing anticipated emissions with the State air toxics list.

- Estimate emissions of toxic air pollutants, using procedures approved by the State.

- Estimate offsite concentrations, normally by air quality modeling procedures approved by EPA or the State.

- Compare offsite concentrations to permissible State levels.

- If a new source is likely to exceed the State limits, require additional controls beyond what would otherwise be required.

In summary, State ARARs will generally include more stringent ambient air quality emission standards compared to Federal ARARs. But the most significant aspect of State ARARs relevant to Superfund air emission sources are the evolving State-specific air toxic programs.

Updated information on State air toxic programs can be obtained from the EPA National Air Toxics Information Clearinghouse (the NATICH telephone number is (919) 541-0850). In addition, EPA-Superfund is currently preparing a document, CERCLA Compliance with Other Laws Manual. When available, this manual should be consulted for a more comprehensive discussion of ARARs.

4.2 Remedial and Removal Applications

Air pathway impacts are evaluated and these results used as input to site-specific cleanup decision making by the RPM and EPM. Therefore, APAs are conducted for various remedial and removal applications including the following Superfund activities:

- Remedial Investigation/Feasibility Studies and Remedial Design
- Records of Decision
- Operation and Maintenance
- Planned Removal Actions.

Following is a discussion of how APAs are used to support Superfund decisionmaking for each of these activities. Recommended procedures for the conduct of these APAs are presented in Section 5.

4.2.1 Remedial Investigations/Feasibility Studies (RI/FS) and Remedial Design

Air pathway analyses are involved in many of the standard RI/FS tasks. The level at which the air pathway is evaluated is task dependent and ranges from reviewing data collected in the field; evaluating ARARs; and evaluating work plans, to performing atmospheric dispersion modeling; air quality sampling; and meteorological monitoring. Of the RI/FS tasks, APAs are applied primarily to those listed below:

- RI/FS Planning
- Field Investigations
- Risk Assessment
- Bench and Pilot Studies
- Remedial Alternatives Screening/Evaluation
- Remedial Design.

An air quality analyst may be involved in all of these RI/FS tasks to assist the RPM/EPM in appropriate reviews and planning. Discussions of APA input to remedial design tasks are also included in this section since these tasks also support activities prior to onsite cleanup activities.

RI/FS Planning --

The air pathway is considered during RI/FS planning to ensure that the air quality evaluation of the various remedial alternatives is properly addressed during succeeding tasks. Available air and supporting data collected in the field are reviewed and analyzed with appropriate input to the plan preparation. If a preliminary risk assessment is to be performed for this task, atmospheric dispersion and emission source modeling may be required for the air pathway exposure assessment.

Field Investigations --

Air quality and emission source sampling may be required as part of the media sampling program. Air modeling can be used to characterize sources for a determination of onsite and offsite impacts and provide input for the design of a monitoring program. In the event that exploratory excavations are undertaken that could have significant releases impacting the air pathway, realtime air support may be necessary. This can involve additional air sampling, meteorological monitoring and dispersion modeling to characterize and mitigate the impacts of potential air releases.

Risk Assessment --

This is another key RI/FS task with regard to the APA. The air quality evaluation supports preparation and analysis of the public health and environmental assessments for the various remedial alternatives. Atmospheric dispersion and emission source modeling can be used with appropriate air sampling data as input to an atmospheric exposure assessment.

Bench and Pilot Studies --

The APA for treatability (bench and pilot) studies primarily involves appropriate air quality and emission source sampling during the conduct of the program. This would enable a review and evaluation of potential air impacts and an assessment of necessary emission control technologies to be applied during the remedial action.

Remedial Alternatives Screening/Evaluation --

APA results can be used as input to the remedial alternatives screening/evaluation task to support analyses and comparisons of remedial alternatives. Results of previous RI/FS assessments can be examined and emission controls for the various remedial alternatives applied to ensure that impacts on public health and the environment are minimized. The air pathway can be a significant consideration in the analysis and comparison of alternatives.

Remedial Design --

APA input to remedial design tasks involves support to any bench and pilot studies accomplished during the design phase and to required environmental permitting. As with the RI/FS treatability studies, APA support could include air quality and emission source sampling and assessment of emission control technologies. Permitting support includes preparation of air-related permits including required documentation. This documentation may involve atmospheric dispersion modeling applications based on RI/FS assessments. Environmental permitting requirements will be defined in the ARAR determinations during the RI/FS and ROD activities.

4.2.2 Records of Decision

An APA is conducted during the Record of Decision (ROD) to ensure that the air pathway has been adequately evaluated in the process of selecting site-specific remedial action. The APA to support the ROD includes review of the RI/FS air quality evaluation. The ROD documents this assessment by discussing potential air impacts, ARARs, and necessary mitigative actions. Any necessary air quality or emission source sampling planned to be conducted during remedial actions or the operation and maintenance phase must also be documented.

4.2.3 Remedial Actions

Remedial activities at Superfund sites may expose individuals located both onsite and offsite to air emissions of hazardous compounds. The APAs for remedial actions provide the information to assess these emissions to determine actual or potential impacts. The specific air pathway evaluation appropriate for a site-specific remedial action depends on two factors. The first is whether any ARARs must be addressed. The second is whether the potential for significant non-routine or routine air releases exists and, if so, whether realtime evaluations of these releases during remedial activities are necessary.

Evaluation of air-related ARARs is accomplished as an RI/FS activity and documented in the ROD for the selected remedial alternative. An example could be applicability of the Federal Clean Air Act requirements for remedial alternatives such as onsite incineration of contaminated soils or air stripping of contaminated groundwater. Should an ARAR trigger an air quality monitoring program during a remedial action, the design and implementation of the program will be based on the ARAR and documented in the monitoring plan.

Realtime evaluations of air emissions are necessary if there is the potential for significant releases or impacts during remedial actions. Assessment procedures must be implemented to evaluate when emergency actions are required. A determination of the need for this realtime air impact assessment capability could be accomplished using a screening atmospheric dispersion modeling approach, which provides a conservative evaluation of potential downwind impacts during various phases of the remedial action. The RI/FS exposure assessment could also be used for this determination. A realtime assessment of air concentrations at a Superfund site may involve a combination of modeling and monitoring methods. This approach enables appropriate site personnel to determine when pre-defined criteria or action levels are reached or exceeded so that safeguards (including evacuations) and/or mitigative actions can be implemented.

4.2.4 Operation and Maintenance

The operation and maintenance stage after site cleanup may also involve compliance with ARARs or project requirements regarding monitoring emissions. This could include the conduct of emissions (source) monitoring or ambient air monitoring. Source monitoring may involve sampling of emissions from vents while ambient air monitoring may be onsite and/or offsite. Collection of air monitoring data may be necessary to ensure compliance requirements are met and that operations are working properly.

Examples of remediated sites that may require monitoring include passive remediations such as venting of a capped landfill, or a no-action alternative involving a covered landfill. Both have the potential for volatile compounds to migrate to the atmosphere through vents, cracks in the cap or soil, or directly through porous soils. Additionally, any soils contaminated from leakage of hazardous compounds may be suspended through wind erosion and deposited at some downwind location. Based on these site conditions, an air monitoring program may be warranted. The air monitoring program may also include meteorological monitoring.

4.2.5 Planned Removal Actions

Planned removal actions (assumed to be those where there is no immediate threat to human health or the environment, but where expeditious removal is warranted), like various remedial actions, may present the potential for significant air releases of hazardous compounds. A determination of whether the potential exists for significant air releases during the activity can be based on the application of dispersion models. If this potential exists, a combination of modeling and monitoring methods can be used to provide realtime assessments to characterize air releases and determine if emergency actions are necessary.

An example activity which may involve significant air releases is the excavation of buried drums which could be ruptured by equipment or which have lost their integrity due to rust or corrosion. Spills of material may then cause impacts via the air pathway. These procedures allow appropriate personnel to determine when pre-defined criteria or action levels are reached or exceeded so that safeguards (including evacuations) and/or mitigative actions can be implemented.

4.3 Application of Data Quality Objectives

Summary of the Data Quality Objective Process--

Data quality objectives (DQOs) are qualitative and quantitative statements that outline the decision-making process and specify the data required to support Superfund decisions during remedial response activities. Superfund guidance for development of DQOs is presented in Data Quality Objectives Development Guidance for Uncontrolled Hazardous Waste Site Remedial Response Activities. (US EPA, October 1986).

The risk of an RPM/EPM making a wrong decision is related to data quality and quantity. As the quantity and quality of data increase, the risk of making a wrong decision based upon the information generally decreases. This is not a true linear relationship since at some point the collection of additional data or improvement of data quality will not significantly decrease the risk of making wrong decisions. The risk of making a wrong decision decreases as data quantity and quality increases, until it reaches a point of diminishing returns, where additional data or increased quality of data does not significantly reduce the risk of making a wrong decision.

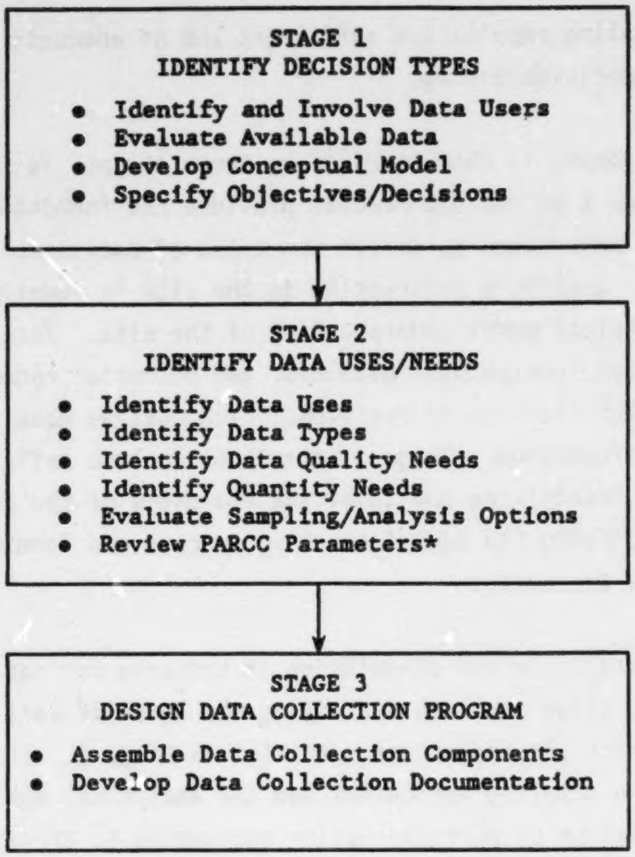
The consequences of a wrong decision must be weighed by the RPM for each major decision to be made during the remedial action process. Where the consequences of a wrong decision carry significant public health, safety, or environmental impacts, greater attention must be paid to obtaining the data required to ensure that the decision is sound. Therefore, the objective of the DQO process as applied to APAs is to ensure that all Superfund air monitoring/modeling results are sufficient and of adequate quality to support site-specific decision making.

The DQO process is characterized by three stages, as illustrated in Figure 3. Stage 1 of the DQO process provides the foundation for Stages 2 and 3. Stage 1 is undertaken to define the types of decisions that will be made. In Stage 1, all available information on the site is compiled and analyzed to develop a conceptual model understanding of the site. This model describes suspected sources, contaminant pathways, and potential receptors. The model facilitates identification of decisions which must be made and deficiencies in the existing information. Stage 1 activities include defining program objectives and identifying and involving end-users of the data. Stage 1 results in specifying the decision-making process and forming an understanding of why new data are needed.

Stage 2 results in the stipulation of criteria for determining data adequacy. This stage involves specifying the level of data certainty sufficient to meet the objectives specified in Stage 1. Stage 2 includes selection of the sampling approaches and the analytical options for the site, including evaluation of multiple-option approaches to effect more timely or cost-effective data collection and evaluation.

Stage 3 results in the specification of the methods by which sufficient data of acceptable quality and quantity will be obtained to make decisions. This information is provided in documents such as the sampling and analysis (S&A) plan or work plan.

Application of the three-stage DQO process to Superfund APAs is illustrated in Figure 4. Stage 1 involves the identification of APA recommendations presented in Volume I, collection and review of APA input data (e.g., reviewing available air monitoring data) with participation by air experts. Stage 2 involves selection of the APA sophistication level, selection of the APA approach (i.e., modeling and/or monitoring), and


STAGE 1
IDENTIFY DECISION TYPES
• Identify and Involve Data Users
• Evaluate Available Data
• Develop Conceptual Model
• Specify Objectives/Decisions
STAGE 2
IDENTIFY DATA USES/NEEDS
• Identify Data Uses
• Identify Data Types
• Identify Data Quality Needs
• Identify Quantity Needs
• Evaluate Sampling/Analysis Options
• Review PARCC Parameters*
STAGE 3
DESIGN DATA COLLECTION PROGRAM
• Assemble Data Collection Components
• Develop Data Collection Documentation

* PARCC
(Precision, Accuracy, Representativeness, Completeness, and Comparability)

Figure 3. Data Quality Objectives - Process Overview.

STAGE 1
IDENTIFY DECISION TYPES

- Identify APA Guidelines Recommendations (Vol 1)
- Collect and Review APA Input Data
- Involve air experts for Potential Off-Site Impacts
- Involve Both Air Experts and Safety Experts/ Industrial Hygienists for Potential On-site Impacts

STAGE 2
IDENTIFY DATA USES/NEEDS

- Select APA Sophistication Level (Vol I)
- Select APA Approach (Modeling Versus Monitoring)(Vol I)
- Evaluate APA Uncertainty (Vol I)

STAGE 3
DESIGN DATA COLLECTION PROGRAM

- Develop APA (Modeling/Monitoring) Plan (Vols II-IV)

Figure 4. Data Quality Objectives - Application to Air Pathway Analyses.

evaluation of the uncertainty of APA results. Stage 3 involves development of a site-specific modeling and/or monitoring plan for implementing the selected APA approach.

Figure 4 illustrates how the DQO process is integrated into the overall APA process. The various components of each DQO stage in Figure 3 directly correspond to the major components of the APA protocol presented in Figure 4. Therefore, the APA recommendations and technical protocols presented in Volumes I-IV are based on application of the DQO process.

SECTION 5
OVERALL PROCEDURES FOR CONDUCTING AIR PATHWAY ANALYSES FOR SUPERFUND

5.1 OVERVIEW

A recommended air pathway analysis (APA) procedure for Superfund is illustrated in Figure 5 and discussed in Section 5.2. This procedure identifies activity-specific and source-specific requirements for the conduct of APAs. Recommendations are presented concerning the selection of the appropriate type of APA for each type of activity or source. This selection process includes evaluation of modeling versus monitoring for the collection of data necessary to complete the APA. The Superfund APA procedure also refers to Volumes II, III, and IV for specific procedures and information needed to conduct the recommended APAs. These volumes contain information for the conduct of emission estimation assessments, air monitoring programs, and dispersion modeling studies.

A five-step standard format typically used for implementing the procedures in Volumes II, III, and IV is given in Section 5.3. The material in these volumes is summarized in Section 5.4 through 5.6. Combined with the recommended Superfund APA procedure, this five-step standard format will provide useful information to the RPMs and EPMs for planning projects. This information should be sufficient for the RPM/EPM to identify the type of APA(s) needed for a particular site/application.

The other three volumes in this series are frequently referred to in this section. Their contents can be inferred from their titles:

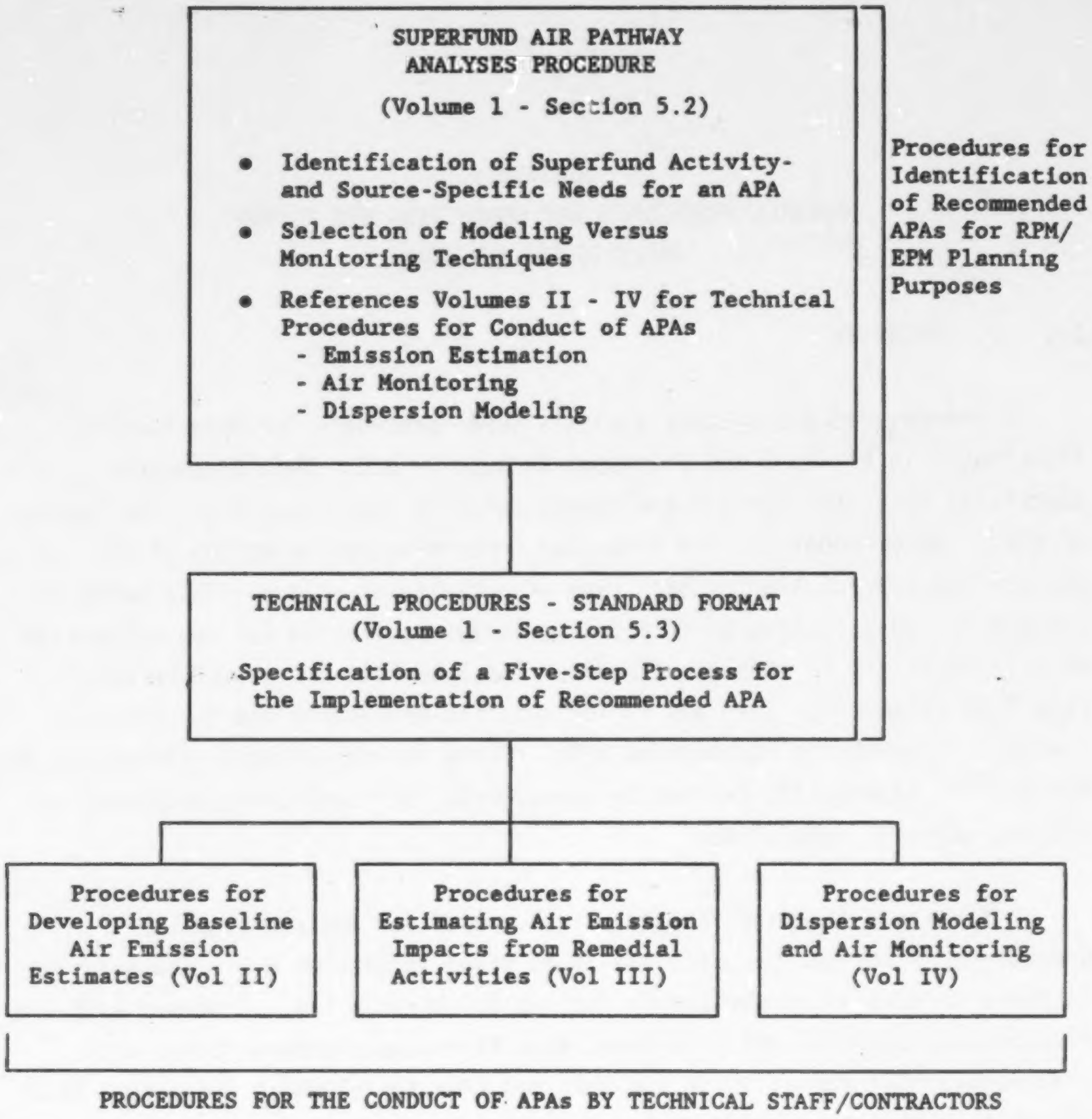

SUPERFUND AIR PATHWAY ANALYSES PROCEDURE
(Volume 1 - Section 5.2)
• Identification of Superfund Activity- and Source-Specific Needs for an APA
• Selection of Modeling Versus Monitoring Techniques
• References Volumes II - IV for Technical Procedures for Conduct of APAs
- Emission Estimation
- Air Monitoring
- Dispersion Modeling
Procedures for Identification of Recommended APAs for RPM/EPM Planning Purposes
TECHNICAL PROCEDURES - STANDARD FORMAT
(Volume 1 - Section 5.3)
Specification of a Five-Step Process for the Implementation of Recommended APA
Procedures for Developing Baseline Air Emission Estimates (Vol II)
Procedures for Estimating Air Emission Impacts from Remedial Activities (Vol III)
Procedures for Dispersion Modeling and Air Monitoring (Vol IV)
PROCEDURES FOR THE CONDUCT OF APAs BY TECHNICAL STAFF/CONTRACTORS

Figure 5. Procedures for Conducting Air Pathway Analyses for Superfund Applications.

- Volume II - Estimation of Baseline Emissions At Superfund Sites.
- Volume III - Estimation of Emissions From Clean-up Activities At Superfund Sites.
- Volume IV - Procedures for Dispersion Modeling and Air Monitoring

5.2 RECOMMENDED SUPERFUND APA PROCEDURE

The recommended APA procedure for Superfund applications is summarized in Figure 6. This procedure involves three segments. The first segment identifies APAs that should be conducted during RI/FS, ROD, and Remedial Design activities. The second segment identifies the APA that should be conducted during remedial or removal actions. The third segment addresses the APA for the post-cleanup (i.e. operation and maintenance) phase. Each segment is described below. The applications of these APAs within the Superfund process have been discussed in Section 4 of this document.

It is important to keep in mind the basic distinction between screening and refined (or "in-depth") techniques, and that the distinction can mean different things for different APA approaches. The basic distinction is that a screening approach is inherently conservative, i.e., that the results represent an upper bound of what the true results might be. Along with its conservative nature, a screen is meant to be simple and utilizes as few resources as possible. The purpose of taking a screening approach is, that if air impacts are acceptable in spite of the conservative nature of the analysis, then the resources needed to conduct a refined or in-depth analysis are conserved.

For APA approaches involving predictive modeling, it is relatively easy to conform to this concept of a screen. This is because both emissions models and air quality dispersion models can be run in a conservative fashion, selecting conservative parameters. For example, contaminant concentrations in

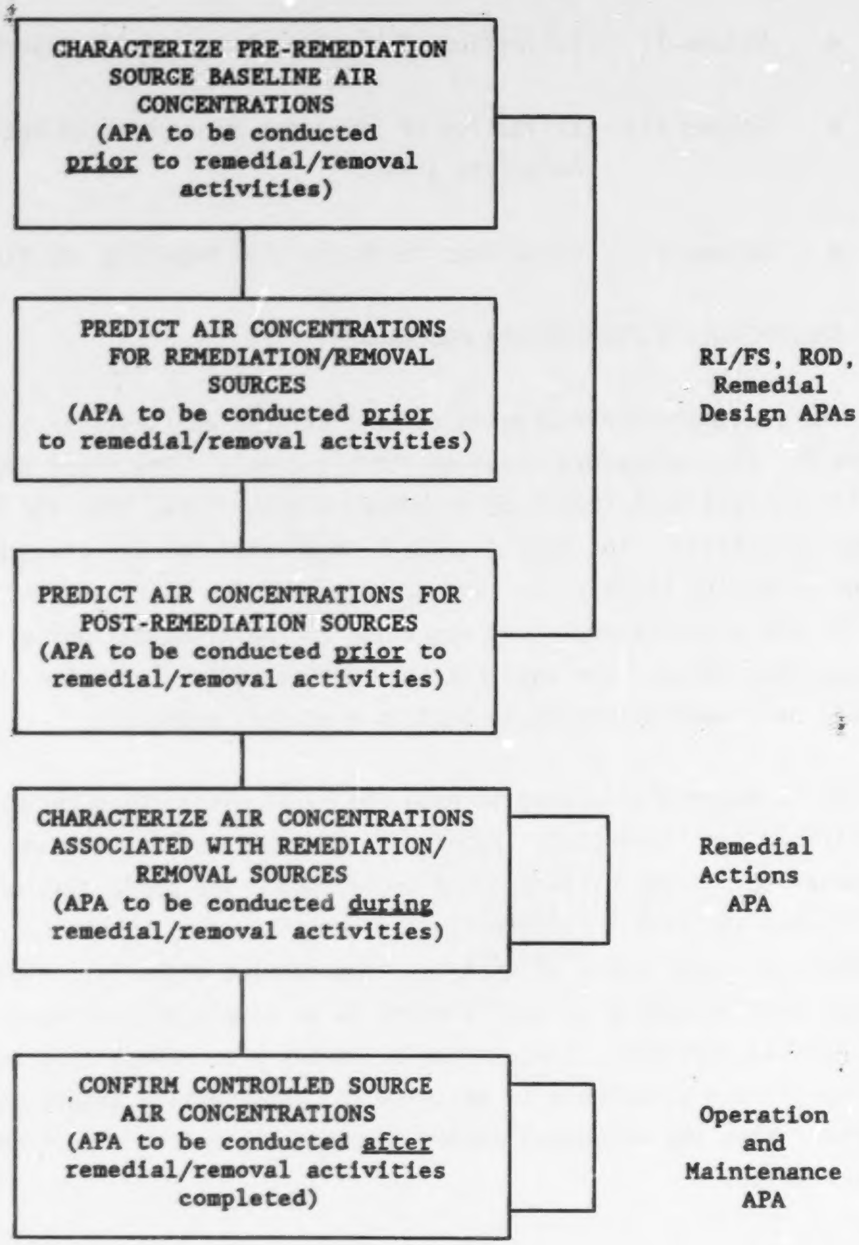

CHARACTERIZE PRE-REMEDIATION SOURCE BASELINE AIR CONCENTRATIONS
(APA to be conducted prior to remedial/removal activities)
PREDICT AIR CONCENTRATIONS FOR REMEDIATION/REMOVAL SOURCES
(APA to be conducted prior to remedial/removal activities)
PREDICT AIR CONCENTRATIONS FOR POST-REMEDIATION SOURCES
(APA to be conducted prior to remedial/removal activities)
RI/FS, ROD, Remedial Design APAs
CHARACTERIZE AIR CONCENTRATIONS ASSOCIATED WITH REMEDIATION/ REMOVAL SOURCES
(APA to be conducted during remedial/removal activities)
Remedial Actions APA
CONFIRM CONTROLLED SOURCE AIR CONCENTRATIONS
(APA to be conducted after remedial/removal activities completed)
Operation and Maintenance APA

Figure 6. Recommended Superfund Air Pathway Analyses - Procedure Overview.

soil or water, or meteorological conditions, etc. can be assigned "worst-case" values. When ambient measurements are involved, either to assist in estimating emissions or attempting to determine downwind impacts, it is no longer possible to ensure that a screening approach is conservative. The reason for this is that ambient concentrations are generally highly variable in space and time, and the few single-point measurements that can be made with monitors run the risk of identifying a "false negative", i.e., missing maximum concentrations altogether. Furthermore, instruments commonly used for screening such as total hydrocarbon analyzers, have detection levels well above levels of concern for many pollutants.

An illustration of the risk of confusing the meaning of a screen is when a total hydrocarbon analyzer is used to provide a "screening estimate" of air impacts. If no air impacts are detected in a site survey it is tempting to conclude that air impacts are not of concern. However, a more accurate conclusion is often that pollutants may have been present at undetectable levels (yet still at levels that are cause for concern), or that emissions were not high on the day of the survey, or that high concentrations were present but not detected by the few point measurements taken. it is thus important both to design screening analyses and to interpret screening results in light of whether inherent conservatism can be assured.

5.2.1 RI/FS, ROD, and Remedial Design APAs

As indicated in Figure 6, APAs should be conducted for the following three source types to support preparation of the RI/FS, ROD, and Remedial Design:

- Pre-remediation Sources;
- Remediation Sources; and
- Post-remediation Sources.

Baseline air concentrations at Superfund sites should be characterized prior to remediation. This should include the following sequence of events:

- Step 1 - Identify/evaluate potential ARARs governing the air pathway for pre-remediation sources.

- Step 2 - Determine pre-remediation emission rates.

- Step 3 - Estimate baseline air concentrations with a dispersion model using emission rate estimates as input.

- Step 4 - Measure baseline air concentrations.

The use of predictive models to estimate emission rates and the resultant air concentrations is a cost-effective basis for initially characterizing the potential spatial and temporal variability of baseline air quality. The estimates can be used to perform a preliminary risk evaluation for the air pathway. It is imperative to consider both short-term (peak) exposures and long-term (average) exposures for on-site and off-site receptors. The estimation procedures can, if designed carefully, provide an upper-bound estimate of air concentrations in the baseline case. Often it is desireable to perform monitoring to evaluate model predictions but not always necessary if the screening evaluation has been performed conservatively. This typically involves an air monitoring program to obtain concentration measurements at strategic locations. By using predictive models, the cost and duration of any subsequent air monitoring can generally be reduced without sacrificing data quality.

Cleanup emissions should also be evaluated to support RI/FS, ROD, and Remedial Design applications. This should include the following sequence of events:

- Step 1 - Identify/evaluate potential ARARs governing the air pathway for remediation and removal sources.

- Step 2 - Estimate emission rates of remediation/removal sources.

- Step 3 - Estimate air concentrations associated with remediation/removal sources using emission rate estimates as input.

This approach does not require monitoring since the concentration estimates are generated prior to remediation or removal for use in planning the eventual remedial action.

Post-remediation air emission sources associated with operation and maintenance activities should also be evaluated to support RI/FS, ROD, and Remedial Design applications. The sequence of steps is:

- Step 1 - Identify/evaluate potential ARARs for post-remediation sources.
- Step 2 - Estimate emission rates of post-remediation sources.
- Step 3 - Estimate air concentrations associated with post-remediation sources using emission rate estimates as input.

The baseline emission estimation procedures presented in Volume II are applicable to post-remediation sources as well, but require revised source/waste characterization data as input. Again, the approach does not require air monitoring since the concentration estimates are generated prior to site cleanup operations to meet the planning needs.

5.2.2 Remedial/Removal Action APA

The second major segment of the Superfund APA procedure, as shown in Figure 6, involves the conduct of an APA in support of, and concurrent with, remedial or removal actions. This should involve the following approach to characterize the air concentrations associated with these remediation/removal sources.

- Step 1 - Identify/evaluate potential ARARs governing the air pathway for remediation/removal sources.

- Step 2 - Perform routine air monitoring during the remedial/removal operations.

- Step 3 - Implement a combination of modeling and monitoring techniques to characterize non-routine air releases.

Air monitoring is the primary approach to characterize routine emissions during remedial or removal operations. This is because the primary purpose of the APA at this stage of the Superfund process is to demonstrate, via actual data, that air concentrations are less than health, safety, and environmental criteria. However, a combination of monitoring and modeling techniques should still be used to characterize unplanned releases. For this application, dispersion modeling results can be used to extrapolate monitoring data obtained at or near the source to downwind receptor locations of interest. Emission modeling may also be useful for evaluating the effect on emissions of changes in operations, waste characteristics, etcetera.

5.2.3 Operation and Maintenance APA

The third major segment of the Superfund APA procedure involves the conduct of an APA to support the operation and maintenance phase of the Superfund process. Therefore, the objective of the APA at this post-cleanup phase is to confirm air impact estimates that were obtained during RI/FS, ROD, and Remedial Design activities. The need for such an APA is generally limited to sources which have the potential to exceed ARAR air criteria if not properly operated and maintained. The following APA approach should, as warranted, be implemented:

- Step 1 - Identify/evaluate potential ARARs governing the air pathway for post-remediation sources.

- Step 2 - Conduct emission monitoring pursuant to ARAR criteria.

- Step 3 - Conduct air monitoring pursuant to ARAR criteria.

Again, because both pre-remediation sources and post-remediation sources involve similar source types (i.e. landfills, lagoons, soil surfaces, and containers), the application of Volume II procedures to this application is appropriate.

5.3 TECHNICAL PROCEDURES

The general format which is the basis of each of the Technical Procedures presented in Volumes II-IV is illustrated in Figure 7. This format provides a common framework for the conduct of emission estimates, monitoring program, and modeling studies. This approach consists of a five-step process as follows:

- Step 1 - Collect and review input information;
- Step 2 - Select APA sophistication level;
- Step 3 - Develop APA plan;
- Step 4 - Conduct APA; and
- Step 5 - Summarize and evaluate results.

Following is a brief discussion of each of these steps.

Step 1 - Collect and Review Input Information

This initial step addresses the process of collecting and compiling existing information pertinent to previous site-specific APAs based on a literature survey. It includes obtaining available source, receptor, and environmental data. Once the existing data have been collected, compiled, and evaluated, data gaps can be defined and a coherent monitoring plan or modeling plan developed based on the site-specific requirements.

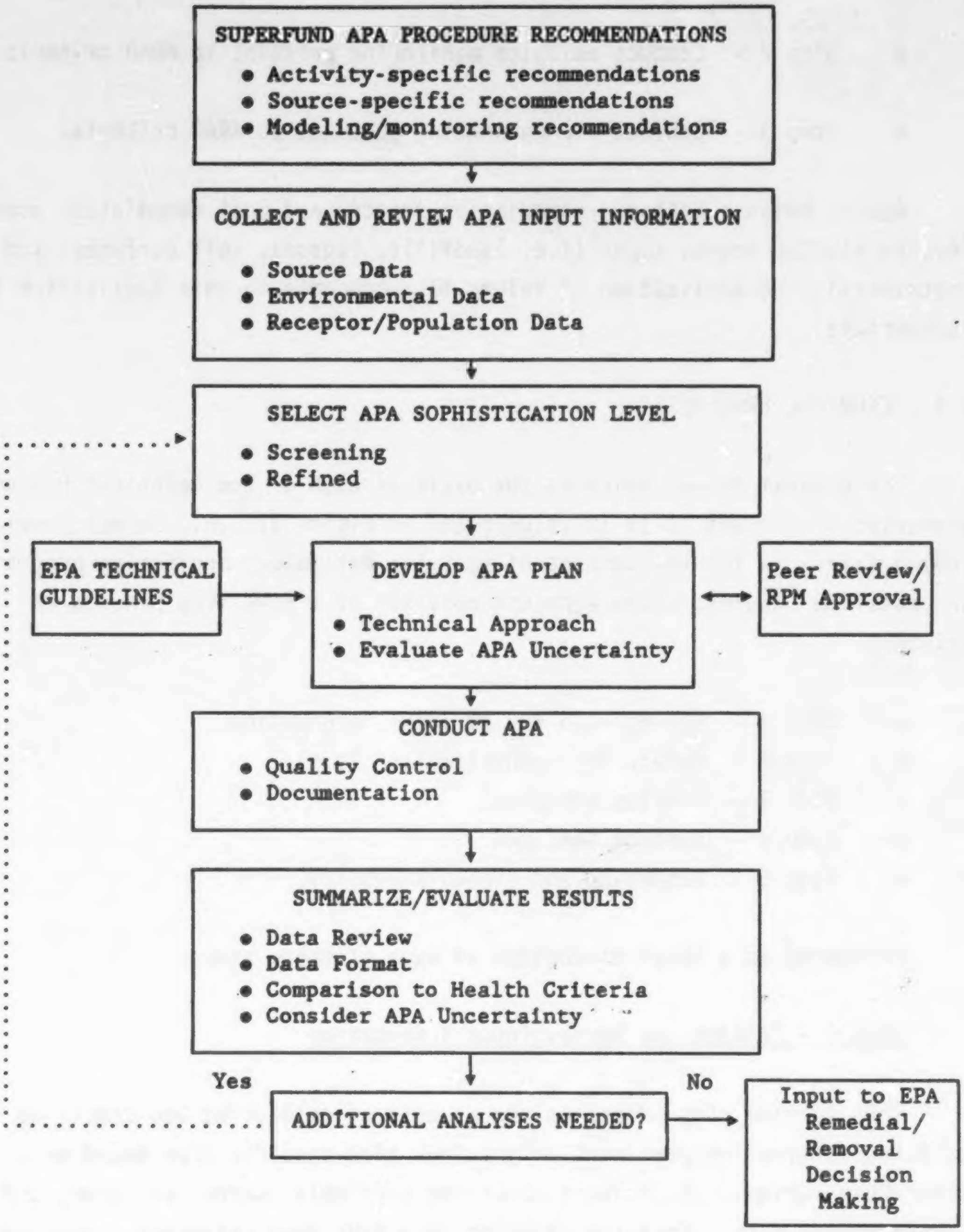

SUPERFUND APA PROCEDURE RECOMMENDATIONS
• Activity-specific recommendations
• Source-specific recommendations
• Modeling/monitoring recommendations
COLLECT AND REVIEW APA INPUT INFORMATION
• Source Data
• Environmental Data
• Receptor/Population Data
SELECT APA SOPHISTICATION LEVEL
• Screening
• Refined
EPA TECHNICAL GUIDELINES
DEVELOP APA PLAN
• Technical Approach
• Evaluate APA Uncertainty
Peer Review/ RPM Approval
CONDUCT APA
• Quality Control
• Documentation
SUMMARIZE/EVALUATE RESULTS
• Data Review
• Data Format
• Comparison to Health Criteria
• Consider APA Uncertainty
Yes
No
ADDITIONAL ANALYSES NEEDED?
Input to EPA Remedial/ Removal Decision Making

Figure 7. Recommended Superfund Air Pathway Analyses Technical Procedures - General Format.

Step 2 - Select APA Sophistication Level

This step involves the selection of the APA sophistication level considering screening versus refined monitoring and modeling techniques. This selection process depends on program objectives as well as available resource and technical constraints. Technical aspects that should be considered include the availability of appropriate monitoring and modeling techniques.

Step 3 - Develop APA Plan

This step involves preparation of an APA plan. The APA should include documentation of the selected technical approach (e.g., non-representative input data, modeling inaccuracies and monitoring limitations). The application of DQOs will be an important aspect in the development of an APA plan. The selected approach should be based on EPA technical quidelines, as available. The APA plan also facilitates peer review of the technical approach and a formal process for approval of the APA by the RPM/EPM. The peer review process may involve EPA air experts or contractor support.

Step 4 - Conduct APA

This step involves the implementation of the APA plan developed during Step 3. The emphasis during Step 4 is to conduct the APA commensurate with appropriate quality control measures and DQO criteria. This also involves documentation of the APA process (to facilitate the QC process and establish an information base that may be useful for APAs at other Superfund sites).

Step 5 - Summarize and Evaluate Results

This step involves reviewing data and evaluating APA results for validity. Additional components of this step should include:

- data processing;
- preparation of statistical summaries;
- comparison of upwind and downwind concentration results; and
- concentration mapping, if possible.

Estimates of data uncertainties based on instrument limitations and analytical technique inaccuracies should also be obtained and used to qualify air monitoring results. Results can be compared to ARAR air criteria and other Superfund health and safety criteria. The results of Step 5 can also provide input to the Superfund risk assessment process.

5.4 ESTIMATION OF BASELINE EMISSIONS

The following description of Volume II is taken from a recent conference presentation (Schmidt and McDonough, 1989). The overall objective of Volume II is to assist RPMs or site managers in assessing the impacts on air quality from the site in its undisturbed condition. Specifically, the manual is intended to:

- Present a protocol for selecting the appropriate level of effort to characterize baseline air emissions;

- Assist site managers in designing an approach for estimating baseline emissions;

- Describe technologies useful for developing site-specific baseline emission estimates (BEEs), which are defined as emission estimates from disturbed and undisturbed sites and are necessary for evaluating a no-action alternative and for evaluating potential emissions during clean-up activities; and

- Help site managers select the appropriate technologies for generating site-specific BEEs.

5.4.1 Protocol for Baseline Emission Estimates

A protocol is presented in Volume II for generating BEEs. While not all sites will require BEEs, the first three steps in the protocol should be implemented to see if BEEs are necessary for a given site. The protocol is a recommended guideline; the level of effort that is required or the need to develop BEEs for individual sites must be determined on a case-by-case basis.

Step 1 - Define the APA Objective

CERCLA and SARA legislation highlight the basic objectives for all remedial investigations. Simply stated, these objectives are to provide data that are "necessary and sufficient" to characterize the "nature and extent" of contamination on site. As the first step of the protocol to assess baseline emissions, site-specific objectives should be developed; this will generally occur simultaneously with the performance of Steps 2 and 3 (data collection and review) of the protocol. Among the types of information that can be reviewed and used to develop site-specific APA objectives are: waste characteristics; distribution of the waste; location of population and community concerns; technical feasibility; and program resources.

Step 2 - Site Scoping

The second step in the development of BEEs is collecting available information about the site. This should be a quick, straightforward information search, involving but not limited to the collection of records, reports, shipping manifests, newspaper clippings, and information from interviews with people living close to or affiliated with the site. For NPL sites, data should be available from the preliminary assessment and site inspection conducted prior to inclusion on the NPL. The type of information to be collected parallels, for the most part, the factors considered in creating the objective.

Step 3 - Evaluate Available Site Data

The existing site information should be evaluated to determine the potential for air pathway contamination. If it is determined through this assessment that the site poses no potential for air pathway contaminant migration, then no further evaluation of the baseline emissions is required. The site manager must record the basis for this decision and include these data in the site investigation documentation. In most cases insufficient information will be available at this stage, and further work will be warranted. If air emissions are a potential concern, the next step of the protocol (site screening study) should be implemented to provide additional information to make a judgement regarding the potential for air emissions from the site. At this point the site-specific APA objectives should be reviewed to ensure they are still realistic, attainable, and applicable.

Step 4 - Design and Conduct the Site Screening Study

Designing a site screening study to assess the air emissions potential involves the selection of an air emissions measurement/assessment technology. The four broad categories of measurement/assessment technologies include:

- Direct emissions measurement;
- Indirect emissions measurement;
- Air monitoring/modeling; and
- Emissions (predictive) modeling.

Each technology can be further categorized according to its level of complexity as screening (quick and simple) or in-depth (very detailed).

The activities necessary to design and conduct the site screening study are:

- Determine the feasibility of obtaining the screening data (identify any site factors that may limit this activity);

- Select appropriate tracer species, screening technologies, and applicable equipment/instrumentation;

- Design the site inspection technical approach and test plan, including the quality assurance/quality control (QA/QC) program. Make sure that all units of a combined site are studied;

- Circulate the site screening approach for review and ensure the screening addresses the site-specific objective(s);

- Modify the site screening program, as necessary;

- Conduct the site screening study and document the findings; and

- Determine if the site screening study was adequate to characterize the air contamination migration pathway and if detailed BEE data are necessary. If detailed BEEs are necessary, initiate the in-depth site characterization study. If not, document the site inspection survey results and the basis for discontinuing the APA.

Step 5 - Design and Conduct the In-Depth Site Characterization

The activities to design and conduct an in-depth study are similar to those described for the screening APA except that in-depth assessment technologies rather than screening technologies are used.

5.4.2 Summary of Baseline Air Emission Measurement Techniques

The recommended technologies are organized into four generic categories: direct emission measurement technologies, indirect emission measurement technologies, air monitoring/modeling technologies, and emissions (predictive) modeling technologies, and in-depth assessment technologies. The screening technologies provide some level of air emission assessment but may not accurately represent the site's potential for air emissions. The in-depth assessment technologies are much more rigorous and generally provide a more accurate estimate of the potential for air emissions from the site. Screening technologies are typically used in the site inspection stage of the remedial investigation (RI), whereas in-depth assessment technologies are typically used during site characterization.

The types of volatile or particulate species that can be measured by the technologies are essentially unrestricted; their measurement depends on the sampling media selected and analysis technique rather than the emission measurement technology. However, few of the technologies are applicable to both volatile and particulate emission rate measurement.

Direct Emission Measurement Technologies

Direct emission measurement technologies are often the preferred technologies for investigating the air pathway. The technologies generally consist of isolating or covering a small section of the site surface or subsurface using a chamber or enclosure. The concentration of emissions produced by the isolated surface is measured within the chamber or from an outlet line. These concentration measurements, along with other technology-specific parameters, are then used to calculate an emission flux or relative concentration valve. The emission flux (rate per area) can generally be related to an emission rate for the entire source.

The cost of the direct emission measurement technologies varies considerably. However, most of the technologies are cost-effective, allowing for several measurements in a given day. Real-time instruments can be used with all the direct technologies to provide immediate data for decision-making during the sampling program, and for the relative ranking of the emission rate at locations across the site. This procedure can be used to reduce the number of samples requiring laboratory analysis by screening for those samples with significant concentrations.

Direct emission measurement technologies, as a class of assessment technologies, are generally preferable to other classes of technologies because they have been proven to be a cost-effective approach for obtaining emission rate and concentration data and they avoid the necessity of modeling to develop BEEs. Direct emission measurement technologies and equipment are generally relatively simple and straightforward.

Indirect Emission Measurement Technologies

Indirect emission measurement technologies generally consist of measuring the atmospheric concentration of the emitted species and then applying these data to an equation (air model) to determine the emission rate. Many of the equations were developed to determine downwind concentrations resulting from stack emissions. For area emission sources, the source is treated as a virtual point source or line source.

The in-depth technologies are very similar as all involve clusters of ambient air samplers positioned very close to the emission source. The concentration profile technique involves a vertical array of samplers directly over the source. The transect technique involves vertical and horizontal arrays of samplers within the downwind plume. The boundary layer technique is a simplified version of the transect technique and involves several downwind samplers, each at a different height.

A disadvantage of indirect emission measurement technologies is that the results are highly dependent on meteorological conditions, interacting source patterns, and uncertainties inherent in the dispersion equations. The indirect technologies require meteorological monitoring to properly align the sampling systems and to analyze the data following sample analysis. Changing meteorological conditions significantly affect the efficiency of collecting useful data. Unacceptable meteorological conditions may invalidate much of the data collected, requiring an additional sampling effort. The technologies also may produce false negative results if the emitted species are present in low concentrations which are below the sampling and analysis detection limits, or if upwind sources cannot be fully accounted for. The technologies also may not be feasible at some sites where the source area is excessively large, or where insufficient space exists downwind of the source to set up the sampling array without disturbance of the air flow pattern by obstructions (e.g., buildings, tanks).

The types of volatile and particulate species that can be measured by the technologies are essentially unrestricted, they depend on the sampling media selected and analysis technique rather than the emission measurement technology.

Indirect emission measurement technologies generally do not provide significant data on the emission rate variability for different locations across a site. This is because the emission concentration is measured downwind of the site after some atmospheric mixing. The technologies generally do not allow for the evaluation of individual contaminated areas at the site unless the areas are separated from one another and are not located upwind of one another.

The costs of the indirect emission measurement technologies vary considerably. The screening technologies are relatively simple and straightforward to implement, and require minimal labor and analytical costs. The in-depth technologies are complex and require considerable equipment, labor, and analysis costs. All of the technologies are subject to data loss or sampling delay due to inappropriate meteorological conditions.

Air Monitoring Technologies

Air monitoring technologies that measure the ambient air concentration resulting from area emission sources are combined with air dispersion modeling to calculate the area source emission rate. The primary difference between indirect emission measurement technologies and air monitoring technologies is the distance at which measurements are made downwind from the source. Indirect measurements are made near the source or units of a combined site (usually on site) and may be able to distinguish between multiple units within a site, depending on the spacing between units. Air monitoring is generally performed at considerable distance downwind from the source and usually cannot distinguish between multiple units within a combined site. Air monitoring typically measures lower concentrations because the contaminant plume is subject to additional air dispersion.

The first step to use the ambient air sampling data to develop emission rate estimates is to select an air dispersion model which accurately reflects the site-specific conditions, including regional and local terrain, typical wind stability, etc. Guidance for selecting an appropriate model for the Superfund source in question can be found in Volume IV of this series. The models are used with air monitoring and meteorological monitoring data to estimate emission rates.

Air monitoring and air dispersion models are used to determine the emission rate through an iterative process. An emission rate is first estimated for the area source. This estimated emission rate, along with meteorological data collected during air monitoring, is used to calculate a predicted downwind concentration. The predicted concentration is then compared to the measured downwind concentration. Based on this comparison, the estimated emission rate is adjusted appropriately, and the process is repeated until acceptable agreement is reached between the measured and predicted downwind air concentrations. The success or failure of this technique depends on designing the monitoring network appropriate for the concentration gradients and averaging times of concern. Guidance contained in Volume IV of this series can be consulted to determine what kind of network is necessary.

Emissions (Predictive) Modeling

Emissions models have been developed to predict emission rates for a variety of waste site types including landfills without internal gas generation, landfills with internal gas generation (typically co-disposal sites), open dumps, waste piles, spills, land treatment operations, aerated lagoons, non-aerated lagoons, and lagoons with an oil film. These models are almost exclusively theoretical, and each model is generally applicable to only one type of waste site.

The predictive models can be used as screening or in-depth technologies. Emissions models, used as screening technologies, use data that can be obtained or calculated from information available in the literature, or can be assumed with some level of confidence. Emission models, used as in-depth technologies, require site-specific site and waste characterization data. The selection of model input sources (site-specific, literature value, or assumed) should be based on the requirements of the decision-making process and the level of resources available. Site-specific data should be used whenever possible to increase the accuracy of emission rate estimates. Each model requires estimating the emission rate of the individual components of the waste; and then summing the emission rates to determine the overall emission rate. For complex waste, application of the models is best performed on a computer to speed the calculation. An emission flux can be calculated by dividing the emission rate by the emitting area.

A wide variety of variables are associated with each of the predictive models; however, a number of key inputs are required by many of the models. These key inputs for landfills include: the vapor diffusion coefficient through the soil or mass transfer coefficient across the air/soil boundary for waste constituents; the physical size of the source expressed as area, length, and/or width, depending on the model used; physical parameters of the landfill cover, such as depth of cover, permeability, and soil porosity (total, air-filled, and/or effective porosity); physical/chemical parameters of the waste, including chemical composition, weight or mole fraction for constituents, vapor concentration of constituents at the waste surface or within the soil cover, and partial pressures of constituents; atmospheric conditions, such as temperature, wind speed and direction, and barometric pressure; and estimates of the soil gas velocity through the soil cover. The key inputs for lagoons include: mass transfer coefficients; physical/chemical parameters of the waste, including chemical composition, weight or mole fractions, partial pressures, and Henry's Law Constants; physical dimensions of the lagoon surface; atmospheric conditions, such as temperature, and wind speed and direction; layering of waste within the lagoon; and physical/chemical parameters of a surface crust.

While all of these parameters can be estimated with varying levels of confidence, it is best, when possible, to collect site-specific data. Physical/chemical measurements of waste constituent can be obtained from sampling and analysis programs, although a records review is advisable to identify key constituents and ensure representative sampling. Likewise, a sampling and analysis program combined with a records search is desirable to determine the physical size and shape of the source and the porosity and permeability of any soil cover. Atmospheric conditions are easily obtained from various weather services which can provide regional data; however, collecting some site-specific meteorologic data to ensure representativeness is desirable. Diffusion and mass transfer coefficients are typically calculated based on the wastes' chemical composition and their known chemical properties, such as Henry's Law Constants, although tabulated diffusion coefficients are now available. The referenced literature includes suggested methods for calculating the diffusion coefficients as well as some tabulated data. Diffusion and mass transfer coefficient can also be determined experimentally in the lab; however, disturbance of the waste and landfill cover to obtain site-specific materials would probably introduce uncertainty.

Screening and In-Depth Technologies

Volume II describes measurement technologies as "screening" and "in-depth" assessment technologies which can be used to support screening APA (Step 3 of the protocol) and detailed APA (Step 5 of the protocol), respectively. Screening assessment technologies are listed and described in Table 7 and in-depth assessment technologies are listed and described in Table 8. Applications for specific assessment technologies, as well as advantages and disadvantages or limitations of these technologies, are provided. Volume II provides discussion of these technologies so that an RPM could make a decision on the selection and use of a technology for a site specific APA.

TABLE 7. SUMMARY TABLE OF INFORMATION ON THE VARIOUS CLASSES OF ASSESSMENT TECHNOLOGIES AND SCREENING ASSESSMENT TECHNOLOGIES

Class of Assessment Technology	Application	Advantages	Disadvantages
● Direct Emission Measurement	Landfills and lagoons, especially if identification of BEEs per units on a combined site is required.	High precision and accuracy, measures undisturbed BEE without modeling, can distinguish between units if combined site.	Heterogenoeous waste will require higher number of measurement points for representative BEE.
Head Space Sampler	All landfills; lagoons (non-aerated) with flotation device.	Representative of volatile emissions potential.	Sampling devices required. Representativeness must be considered.
Head Space Sample in a Bottle	All landfills and lagoons where you have a sample of the waste.	Rapid screening technology that is easy to perform.	Can lose a significant fraction of the volatile species during handling. Representativeness must be considered.
● Indirect Emission Measurement	Larger landfills and lagoons and sites with waste handling activities, combined sites.	Assess BEE from an area source, regardles sof homogenisty and site activity. Can be used for inaccessible sites.	Limitations imposed by modeling, techniques are influenced by meteorological conditions, may not be able to distinguish between units of a combined site or upwind interference.
Upwind/Downwind	Landfills and lagoons (any area source).	Broadly applicable and can provide an estimate of emissions.	Single point ambient measurements may not represent the emission source.
Mass Balance	Lagoons and some landfills.	Limited resources are required.	Requires concentration data over time, inherent insensitivity due to low mass of volatile species.
Real-Time Instrument Survey	Landfills and lagoons (any area source).	Rapid, real-time data that can be used to indicate emissions potential.	Highly variable, quality control program for analyzers required.
o Air Monitoring/ Modeling	Landfills and lagoons (any area source).	Typically provides data that represents air concentrations the community is exposed to (fence line).	Limitations imposed by modeling, techniques are influenced by meteorological conditions, analytical sensitivity may be a limiting factor.
Upwind/Downwind	Landfills and lagoons (any area source).	Broadly applicable, provides community ambient concentration data.	Low concentrations with high variability, measurement subject to meteorological influences.

(Continued)

TABLE 7. (Continued)

Class of Assessment Technology	Application	Advantages	Disadvantages
o Emissions Modeling (Predictive)	Landfills and lagoons, especially applications with site-specific information.	Provide rapid, inexpensive assessment, particularly where only a few species are of concern. Model inputs can be assumed or taken from literature if site-specific data is not available.	Accuracy, precision dependent on quality of site-specific data or assumptions. Most models have limited validation.
	- Closed landfills, no gas generation.	Same	Same
	- Closed landfills, gas generation.	Same	Same
	- Open landfills.	Same	Same
	- Land treatment.	Same	Same
	- Non-aerated lagoons.	Same	Same
	- Aerated lagoons.	Same	Same

TABLE 8. SUMMARY TABLE OF INFORMATION ON THE VARIOUS CLASSES OF ASSESSMENT TECHNOLOGIES AND IN-DEPTH ASSESSMENT TECHNOLOGIES

Class of Assessment Technology	Application	Advantages	Disadvantages
• Direct Emission Measurement	Landfills and lagoons, especially if identification of BEES per units on a combined site is required.	High precision and accuracy, measures undisturbed BEE without modeling, can distinguish between units if combined site.	Heterogeneous waste will require higher number of measurement points for representative BEE.
Emission Isolation Flux Chamber	Landfills-active, inactive, soil contamination, waste piles; lagoons (non-aerated) with flotation on device.	High precision and accuracy, measures undisturbed BEE without modeling, can distinguish between units if combined site.	Heterogeneous waste will require higher number of measurement points for representative BEE.
Soil Probe (Volatiles)	Landfills-active, inactive, soil contamination, waste piles; lagoons-berms around lagoons, heavy sludges.	Can obtain a subsurface disturbed BEE 1 to 10 feet below land surface without excavation.	Heterogeneous waste will require higher number of measurement points for representative BEE.
Downhole Emission Flux Chamber (Volatiles)	Landfills-active, inactive, soil contamination, waste piles; lagoons-berms around lagoons, heavy sludges.	Can obtain a subsurface disturbed BEE 1 to 100 feet below land surface with a hollow stem auger drill rig.	Layered or stratified waste will require BEE for each discrete layer.
Vent Sampling (volatiles)	Waste repositories with passive or active venting system, common at municipal, and co-disposal landfills.	Simple BEE measurement procedure.	Often difficult to measure low gas flow rates which causes imprecision and inaccuracy, include sampling schedule that identifies diurnal variations/other factors that influence gas production.
Wind Tunnel Measurement (volatiles and/or particulate matter)	Specialized for particulate emissions from waste piles and solid surfaces, landfills, lagoons (non-aerated) with flotation on device.	BEE for particulate matter and/or volatiles as a function of wind speed.	Heterogeneous waste will require higher number of measurement points for representative BEE, additional support equipment needed to produce simulated wind speed.

(Continued)

TABLE 8. (Continued)

Class of Assessment Technology	Application	Advantages	Disadvantages
● Indirect Emission Measurement	Larger landfills and lagoons and sites with waste handling activities, combined sites.	Assess BEE from an area source, regardless of homogenisty and site activity. Can be used for inaccessible sites.	Limitations imposed by modeling, techniques are influenced by meteorological conditions, may not be able to distinguish between units of a combined site or up-wind interference.
Concentration-Profile (volatiles)	Lagoons, landfills-large solid waste site and contaminated soil.	Specialized measurement and modeling technique, high precision and accuracy for an indirect technique	Must meet meteorological conditions of technique, not well suited for small waste areas, sophisticated support equipment required.
Transect (volatiles/ particulate matter)	Lagoons, landfills-large or small sites.	Specialized measurement and modeling technique, can be used for particulate matter from waste handling.	Must meet meteorological conditions of technique, technique influenced by meteorological conditions.
Boundary Layer (volatiles)	Lagoons, landfills-large or small sites.	Specialized measurement and modeling technique, can be used for particulate matter from waste handling.	Must meet meteorological conditions of technique, technique influenced by meteorological conditions.
● Air Monitoring/ Modeling	Landfills and lagoons, complete site emissions, monitoring at downwind distances greater than indirect emission measurement.	Typically provides data that represents air concentrations the community is exposed to (fence line).	Limitations imposed by modeling, techniques are influenced by meteorological conditions, analytical sensitivity may be a limiting factor.
Concentration-Profile (volatiles)	Not typically used for downwind measurements.	None.	Modeling may not predict emissions from data taken downwind.
Transect (volatiles/ particulate matter)	Lagoons, landfills (any waste site or waste handling treatment for total site emissions).	Generally applicable to most situations.	Limitations imposed by modeling, techniques are influenced by meteorological conditions, analytical sensitivity may be a limiting factor.
Boundary Layer (volatiles)	Lagoons, landfills (any waste site or waste handling treatment for total site emissions).	Generally applicable to most situations.	Limitations imposed by modeling, techniques are influenced by meteorological conditions, analytical sensitivity may be a limiting factor.

(Continued)

TABLE 8. (Continued)

Class of Assessment Technology	Application	Advantages	Disadvantages
• Emissions Modeling (Predictive)	Landfills and lagoons, especially applications with site-specific information.	Provide rapid, inexpensive assessment, particularly where only a few species are of concern. Model inputs can be assumed or taken from literature if site-specific data is not available.	Accuracy, precision dependent on quality of site-specific data or assumptions. Most models have limited validation.
AP-42 Dust Emissions for Vehicles (particulate matter)	Road dust.	Established EPA-approved model.	Accuracy depends on quality site-specific data.
Covered Landfill Models (volatiles)	Covered landfills.	Provide rapid, inexpensive assessment. Models can be selected based on available input data. Can account for bio-gas generation at co-disposal sites.	Accuracy, precision, dependent on quality of input data. Do not account for losses to other pathways.
Open Dump Models (volatiles)	Open Landfills.	Account for non-steady state emission (i.e., declining emission) over time.	Accuracy, precision dependent on quality of input data. Do not account for losses to other pathways. Do not account for bio-gas generation.
Lagoon Models (volatiles)	Lagoons, with or without aeration.	Provide rapid, inexpensive assessment. Models can be selected based on available data.	Accuracy, precision dependent on quality of input data. Do not account for losses to other pathways. Assume constant source strength over time.

5.5 ESTIMATION OF EMISSIONS FROM CLEAN-UP ACTIVITIES

The following description of Volume III is taken from a recent conference presentation (Eklund and Summerhays, 1989). Volume III is intended for estimating air impacts as part of the evaluation of alternative remedial options (e.g. incineration versus air stripping versus removal). It summarizes information obtained from a literature search. The manual can also be used for estimating emissions once a specific remedial action has been selected. For example, it can be used to estimate the air impact from altering the rate of clean-up or changing some other key engineering parameter for a given remedial technology. It also provides guidance on control technologies.

The manual provides the important function of standardizing the air pathway analysis (APA) for remediation of NPL sites, thereby ensuring that a uniform and systematic approach is followed for the diverse universe of NPL sites. The manual provides a step-by-step protocol for estimating air quality emissions resulting from site mitigation. For each step, a three tiered approach is presented. In order of preference these are:

1) Use of site-specific data;

2) Use of predictive contaminant transport models using site-specific inputs; and

3) Use of tabulated default values for when site-specific information is unavailable.

Therefore, emission estimates can be estimated despite limitations in the knowledge of the site. Of course, the confidence of the emissions estimate depends on the associated confidence of the inputs to the estimation procedure. In general, the required information to develop an emission estimate is: the volume of waste present, the average concentration of the given contaminant in the waste, and the form of the waste (liquid versus solid versus sludge).

5.5.1 Potential Emissions By Source Type

The potential emissions of concern for thermal destruction, groundwater stripping, soil vapor extraction, soils handling, and fixation/stabilization are described in the following paragraphs.

Thermal destruction is an engineered process in which controlled combustion is used to decompose the chemical structures of organic compounds, thereby substantially reducing the volume and toxicity of the hazardous components of the waste. A variety of thermal destruction technologies exist, with various types of incineration being the most commonly used. Thermal destruction technologies are required to show that they can achieve at least 99.99% destruction and removal efficiency for toxic organic compounds under ideal conditions. Other pollutants which may be present in the incinerator exhaust gas include trace metals, particulate matter, carbon monoxide, nitrogen oxides, sulfur oxides, and hydrogen chloride. In addition to stack emissions, significant air emissions may result from fugitive losses arising from handling of the waste feed and the ash and other by-products that are produced.

Air stripping of ground water effectively transfers volatile organic contaminants from the liquid-phase to the gas phase. Typically in an air stripping tower, contaminated ground water is introduced at the top of the tower, and passes down through packing media while air is forced through the tower counter-current to the water flow. For volatile compounds, removals in excess of 99.5% have been demonstrated. Emissions of semi-volatile organic compounds may also be a concern. It is generally effective to treat the VOs in the exhaust gas from the stripper using carbon adsorption or incineration.

Soil vapor extraction (SVE), or in-situ venting, uses soil aeration to treat subsurface zones of contaminated soil for volatile organics. Generally, SVE systems consist of a network of vapor recovery wells connected to a vacuum source. The wells are screened over the soil layer of interest. Make-up air permeates down from the ground surface or may be injected to the subsurface via an air intake well. Volatile organics are the main emission type, though some semi-volatile compounds may also be extracted. Treatment after the vacuum source by carbon adsorption or other means is typically possible.

Soils handling covers a wide variety of operations that may result in area-wide sources of fugitive emissions. These include: excavation (backhoe, dragline, bulldozer, etc.), short and long haul transport, dumping, grading, and storage piles (both active and inactive). The primary emissions of concern are particulate matter and volatile organics; metals or other toxics present in the particulate matter may also be a concern at some sites. Control technologies generally involve designing the remedial action plan to minimize the opportunities for emissions to occur and use of foam or water sprays during remediation to temporarily reduce emissions.

Stabilization/solidification processes are currently being developed and evaluated for hazardous waste applications. Stabilization processes reduce the hazard potential of a waste by converting it to its least soluble, mobile, or toxic form. The physical nature or handling characteristics of the waste are not necessarily changed by the technique. Solidification processes (encapsulation processes) bind the waste in a structurally sound, uniform solid. For both processes, wastes are loaded into a mix bin and other materials are added in either a batch or continuous process. Therefore, these processes generally require removal of the soil/waste from its original location. Emissions of concern are particulate matter and volatile hydrocarbons. The latter emissions may be enhanced by the exothermic nature of many of these processes.

5.5.2 Screening Considerations

Basic considerations for making a gross estimate of emissions due to remedial activities are given below. It is intended to be used as a screening tool to assess whether emissions from remediation may be significant at a given site, using a given remedial technology. Sites that have the potential for significant emissions, based on this screening, should have their emissions potential subsequently evaluated using the more precise estimation procedures for each remedial technology given elsewhere. The screening procedure is necessarily conservative, i.e., sites with any likelihood of significant emissions are referred to the more precise, but more time consuming, estimation procedures.

The necessity of evaluating air emissions for a given site is dependent on the type of hazardous material(s) at the site, the size of the site, and the proposed treatment options. The following information should be known to initially assess the emissions potential of the site:

- Estimate the volume (m^3), mass (kg), and type of waste material to be treated;
- Estimate the concentration of VOCs, heavy metals, dioxins, asbestos, and pesticides in the waste material (ug/g);
- List the probable treatment options and control technologies; and
- Estimate the operating rate for remedial activities.

Table 9 lists remedial options and their associated control technologies. Typical operational rates and air emission values for various remedial options are presented in Table 10.

TABLE 9. CONTROL TECHNOLOGIES AVAILABLE FOR EACH REMEDIAL OPTION

Remedial Operation	Contaminant	Control Technology
Incineration	Hydrocarbons	Afterburner, Operational (in-furnace) methods
	Particulate	Venturi scrubber, Electrostatic precipitator, Ionizing wet scrubber, Fabric filter (baghouse)
	Acid Gases	Spray dryers, ionizing wet scrubber, venturi scrubber
	NO_x	Catalytic reduction, Operational (in-furnace) methods
	Fugitives	Inspection/maintenance
Ground Water Stripping	Hydrocarbons	Condensation Carbon adsorption (disposable) Carbon adsorption (regenerable) Incineration
In-situ Venting	Hydrocarbons	Condensation Carbon adsorption (disposable) Carbon adsorption (regenerable) Incineration
Soils Handling		
Excavation	Particulates, Hydrocarbons	Water sprays of active areas Dust suppressants Surfactants Foam coverings
Transportation	Particulates, Hydrocarbons	Water sprays of active areas Dust suppressants Surfactants Road carpets Road oiling Speed reduction Coverings for loads

(Continued)

TABLE 9. (Continued)

Remedial Operation	Contaminant	Control Technology
Soils Handling (Cont.)		
Dumping	Particulates, Hydrocarbons	Water sprays of active areas Water spray curtains over bed during dumping Dust suppressants Surfactants
Storage	Particulates, Hydrocarbons	Windscreens and other enclosures Orientation of pile Slope of pile Foam covering and other coverings Dust suppressants
Grading	Particulates, Hydrocarbons	Light water sprays Surfactants
Stabilization/ Solidification	Particulates, Hydrocarbons	Enclosure of mixing area/apparatus Storage pile controls for raw materials Enclosure of binder preparation area Suction hood (in-situ treatment)

TABLE 10. SUMMARY OF TYPICAL AIR EMISSION VALUES BY SOURCE TYPE

Remedial Option	Typical Operation Rate	Uncontrolled Emissions		Controlled Emissions	
		PM	VOC	PM	VOC
Incineration	650 m^3/min[a] 50,000,000 BTU/hr	0.5-23 g/m^3	0.1-500 ug/m^3	34-110 mg/m^3	-
Air Stripping	3500 L/min	0	5-50 kg/day[b]	0	50-100 ppm[c]
In-situ Ventilation	0.15-0.85 m^3/min[d]	0	1-110 kg/day	0	50-100 ppm[c]
Excavation					
Backhoe	900 m^3/day	0.002-0.22 kg/ metric ton	-	-[e]	-
Dragline	700 m^3/day	-	-	-	-
Scraper	340-610 m^3/day	-	-	-	-
Bulldozer	1100 m^3/day	-	-	-	-
Grading	-	0.03-5.4 kg/hr	-	-[e]	-
Transport					
Unpaved Roads	5 trucks/hr	1.3 kg/VKT	-	-[e]	-
Paved Roads	5 trucks/hr	0.022-0.15 kg/ VKT	-	-[e]	-
Dumping	24-270 m^3/day	0.005-0.16 kg/ metric ton	-	-[e]	-
Storage	-	0.39-1.5 g/m^2/ day	-	-[e]	-
Stabilization	-	0.31-0.41 kg/ metric ton	-	-[e]	-

[a] Exhaust gas rate.

[b] Assume 1-10 mg/L pollutant.

[c] 95-99% efficiency for gas streams of 1000-10,000 ppm VO. Multiple treatment units may feed a single control system.

[d] Exhaust gas rate per recovery well.

[e] Assume control efficiency of 50%.

Note: "-" implies insufficient data to generate typical value.

No clear-cut rules-of-thumb exist for screening which remedial actions are likely to have significant emissions and which remedial actions are not. Only a quantitative evaluation of emissions and their impacts can show the significance of a remedial action. Nevertheless, considerations based on common sense may be used to make qualitative judgments of potential significance. If any of the conditions below are met, then a more rigorous review is recommended.

1. Off-site receptors are near (e.g., within 1 km) of the emission source.

2. The contamination includes any volume of dioxins or areas containing highly concentrated pesticides, volatile carcinogens, or asbestos, and the material will be handled or exposed.

3. The total contamination (mass x concentration) of pesticides, toxic metals, volatile carcinogens, or asbestos at the site is substantial (e.g., exceeds 100 kg), and this material will be handled or exposed.

4. The total contamination (mass x concentration) of VOCs at the site is substantial (e.g., exceeds 1,000 kg VOCs), and this material will be handled or exposed.

5. Volatile organic contaminants are to be treated by incineration, groundwater stripping, or in-situ ventilation, and no emissions controls are to be used.

6. There is reason to believe the control technology will not be effective for some toxic compounds present in the waste.

7. The anticipated operating rate is relatively large (e.g., >10 times the values given in Table 10.

Note that sites with insignificant impacts on any off-site areas may still have an impact on the health and safety of on-site workers, and appropriate precautions should be followed.

5.5.3 Detailed Procedures

Simple equations are presented in Volume III for estimating emissions from various remedial action alternatives. Predictive models are being developed by EPA or industry for all the emission sources discussed in this paper, but none of the emission models are fully developed and validated at this time. Two examples of detailed procedures are presented below, one for organic emissions from incineration and one for organic emissions from air stripping of ground water.

Incineration

RCRA mandates that the principal organic hazardous components be 99.99% destroyed or removed. Additional requirements dictate a limit on particulate emissions of 180 mg/standard m^3 (0.08 grains/standard ft^3). Similarly, for wastes containing dioxins or polychlorinated biphenyls (PCBs), TSCA requirements generally apply that dictate a destruction and removal efficiency of 99.9999% of these pollutants.

A default approach to estimating emissions from thermal destruction of hazardous waste is to assume that the requirements of RCRA and TSCA will be exactly met. If emissions are to be estimated in a feasibility study or otherwise prior to incinerator design, then this default approach may be the only option for estimating emissions. After the incineration is designed, three additional options for evaluating actual emissions more precisely may be available. The first and most rigorous method for emissions estimation would be to perform a trial burn on the waste in question or a similar waste and sample the influent and effluent streams for the pollutant of concern. Where this is not technically or economically feasible, a second approach using theoretical or empirical equations correlating incinerator operating parameters to pollutant emission rates is desirable. In the absence of applicable correlations, a third approach is to use data accumulated from the various trial burns that have been conducted, and assume the results are applicable to the site in question.

To estimate the uncontrolled emissions of organic compounds from this unit, use the following procedure:

$$ER_i = ((1-(DRE/100))/1000)(C_i)(m_w) \qquad \text{(Eq. 1)}$$

where:

ER_i = emission rate for pollutant i (kg/hr);
DRE = appropriate DRE value (e.g., 99.99%);
m_w = mass flow rate for waste feed (kg/hr); and
C_i = waste feed concentration for pollutant i (g/kg).

Air Stripping of Ground Water

Air stripping towers can achieve nearly complete removal of volatile organics from ground water, so emissions estimates can be based on the rate at which contaminants are being treated, i.e. concentration x flowrate. For volatile organics, the emission rate can be estimated as:

$$ER_i = (C_{i,in})(Q_{in})(10^{-6})(1-(CE/100))(RE/100) \qquad \text{(Eq. 8)}$$

where:
ER_i = emission rate for species i (g/min);
$C_{i,in}$ = concentration of species i in influent ground water (ug/L);
Q_{in} = flow rate (L/min);
RE = removal efficiency (%); and
CE = control efficiency (%).

Default values of 99.5% removal efficiency and 1000 liters per minute flowrate can be assumed if design specifications are unavailable.

For semi-volatile organic compounds or inorganic contaminants, the removal efficiency from air stripping may be assumed to be 0%. If site-specific data are available, emissions can be calculated using Equation 10.

$$ER_i = \frac{(C_{i,in})(Q_{in}) - (C_{i,out})(Q_{out})}{10^6} \qquad \text{(Eq. 10)}$$

where: $C_{i,out}$ = concentration of species i in effluent (ug/L); and
Q_{out} = effluent flow rate (L/min).

Note that the flow rates of the influent and effluent streams will differ due to evaporative losses in the air stripping tower.

Emissions are typically either treated by carbon adsorption or left uncontrolled. If on-site incineration is practiced concurrently, then the exhaust can usually be used as make-up air to the incinerator. Control efficiency of carbon adsorption systems will vary with the inlet gas VO concentration, the type of VOs present, and the molecular weight of the compounds. Assume that compounds with molecular weights less than 45 have a control efficiency of 0% and compounds with molecular weights greater than 130 have a control efficiency of 100% (they may be permanently bound to the carbon). For compounds with molecular weights between 45 and 130, assume that inlet streams of 200-10,000 ppm VO can be treated with exhaust gas concentrations of 50-100 ppm typically obtainable. Inlet streams with over 10,000 ppm VOs are candidates for liquid recovery techniques.

5.6 DISPERSION MODELING AND AIR MONITORING PROCEDURES

The following description of Volume IV is taken from a recent conference presentation (Garrison and Cimorelli, 1989). Volume IV contains a five-step procedure for carrying out an APA, and provides details on how to carry out each step for each of the two major approaches, i.e., modeling and monitoring. In the document, each approach is described in a separate section, but here, the two approaches are described together for each step. This is meant to highlight their similarities and differences. The five-step procedure is intended to be consistent with the Superfund Data Quality Objective (DQO) process, at least in a qualitative sense. Consistency is achieved by designing the steps to focus initially on simple, conservative analyses and only refining if previous steps indicate that it is necessary. The quantitative part of the DQO process involves setting numerical bounds on the degree of confidence that one can place on the results of an analysis. It has always been problematical for air analyses to specify numerical degrees of confidence. EPA is examining the question of developing numerical DQOs for air, but no results have been incorporated into Volume IV.

The five steps are as follows:

- Step 1 - Review Existing Site Information/Develop APA Inputs;
- Step 2 - Select APA Sophistication Level;
- Step 3 - Develop APA Plan;
- Step 4 - Conduct APA; and
- Step 5 - Summarize and Evaluate Results.

These five steps are discussed in more detail below.

Step 1 - Review Existing Site Information/Develop APA Inputs

In this step information and data relevant to a site's potential air impacts are obtained and reviewed, and inputs required for a modeling exercise or monitoring program developed. This information can guide the analyst and the site manager in developing a coherent, sensible APA involving the appropriate mix of modeling and/or monitoring analyses. The level of detail available for a given site can vary considerably; generally speaking, more information will be available the longer the site has been under investigation. It will probably be necessary at this stage for the air analyst to develop information that is not already available. The information consists of source and pollutant data, receptor data, and environmental data.

Any previous APA results should also be reviewed for information that may be relevant to the current effort.

Source and Pollutant Data

The number and types of source located at the site should be identified, as well as the types of contaminants present and the potential for each contaminant to be released to the atmosphere. The characteristics of the air pollutant should be identified (i.e., gaseous or particulate, or a toxic constituent adsorbed onto dust particles). For a modeling exercise, source dimensions for area and volume sources, as well as stack parameters for stack sources, need to be specified. Emission rates need to be specified as well, which can be determined according to the procedures outlined in Volumes II and III. Short-term maximum emission rates, as well as long-term averages, should be developed, and an effort made to identify emissions variability based on the mechanisms that are active in producing emissions (e.g., soil handling, meteorological conditions). It should be noted that due to the complexity of the emissions mechanisms for some Superfund source types, that the process of specifying an emission rate may in itself involve a fairly complex protocol and field measurements to measure emissions directly or to monitor and "back-calculate" an emission rate based on an assumed concentration distribution.

Specific emission rates and source characteristics are not directly relevant to a monitoring exercise; however, it is almost always advisable to perform modeling as a part of designing the monitoring network. When developing information in preparation for monitoring, it is quite important to know what concentrations of each pollutant are important, i.e., what are the ARARs or risk levels that will determine whether a concentration is acceptable or not. This will have a direct bearing on whether monitoring is possible or not, and also on what type of monitoring approaches can be used. It is also quite important, both for modeling and monitoring, to know what averaging times are important. Much of the risk assessment part of health analyses is based on long-term averages, both for carcinogens and for systemic toxicants for which reference doses have been established. If short-term effects are important, however, the modeling and/or monitoring approach will have to take that into account. In particular, for a few very toxic chemicals, an instantaneous concentration above a certain level can cause immediate adverse health effects, even death. This will have a strong influence on the choice of models and monitoring methods.

Receptor Data

A dispersion model can calculate concentrations at virtually any location. Generally, a gridded receptor field is utilized in a model to identify concentration gradients and maximum concentrations. Population data in the general vicinity of the site, and location of individual residences in the immediate vicinity of the site, should be determined. Sensitive receptors (e.g., hospitals, schools) should also be identified. This information can help design a receptor grid and interpret modeling results in terms of actual exposures to maximum concentrations, and can help in a monitoring network design by focusing on areas of greatest concern.

Environmental Data

This type of information consists generally of climatology, topography, land use classification, and meteorology. Climatological data, especially in the form of wind roses that identify the frequency of occurrence of wind direction, can provide a baseline of information on general wind patterns that may affect transport of pollutants from a site. Local topography can dramatically influence pollutant transport. For example, a site located downslope of an elevated terrain feature might be affected by density-driven flows that have a pronounced diurnal nature. Topographic features can channel and divert large-scale regional wind flow, such that the wind direction on-site can be much different than measurements taken off-site. Land-use classification affects whether the area should be modeled as "urban" or "rural," a choice that must be made as an option in most dispersion models. All of these factors can affect the design and siting of a monitoring program.

Meteorological data is a vital input to a dispersion model. It is important to identify early on in the process whether meteorological data representative of the site is available. Data from the nearest National Weather Service (NWS) station is generally the easiest to obtain; however, it is representative of a broad area only when the area is relatively flat. Without representative meteorological data, a modeling exercise will be driven by "worst-case" conditions. Recalling the definition of a screen discussed above, this is consistent with a conservative approach; however, lack of data sharply limits the options for refining a screening analysis. Because of this, a program to measure on-site meteorological data (unless NWS or other available data can be considered representative) should always at least be considered as soon after listing a site on the NPL as possible. A procedure for developing an on-site data base is included in Volume IV.

Step 2 - Select APA Sophistication Level

In this stage of the APA process, a decision is made as to what level of sophistication will be employed in the analysis and what models and/or monitoring techniques will be used. A modeling exercise will almost always start out with a screening approach, and steps to refine the analysis are taken only if screening results indicate unacceptable concentrations An exception to this sequence of events might be to take a more refined approach initially if the input data are readily available and the additional effort would not have a significant impact on resources.

Selecting a model is an important part of this step. For most Superfund sources, the Industrial Source Complex (ISC) model, in its short-term (ISCST) and long-term (ISCLT) versions, is directly applicable. The model can be run in a screening mode for short-term predictions. Development of modeling guidance is continuing and revisions should be investigated prior to developing a modeling plan. For example, an effort is underway as a follow-up to Volume IV to develop a long-term screen, i.e., an application of ISC for long-term concentrations in instances when a site-specific frequency distribution of meteorological inputs is not available. Additional reviews of

IC are underway to examine and possibly modify the area source algorithm in the model. This is particularly important for Superfund sources since many of them are modeled as area sources. The updated version of EPA's screening procedures (EPA, 1988c) for point sources contains a computerized version of the document, called the SCREEN model, that can also find useful application for Superfund sources.

The sequence of events in a monitoring exercise is different than that of a modeling exercise; namely, that a "screening" monitoring approach is not necessarily conservative. Nonetheless it is useful to think of monitoring in terms of screening and refined approaches with a different meaning. Screening monitoring techniques are generally associated with relatively high detection levels (i.e., in the range of parts per million for gaseous contaminants) and frequently provide near real-time results in the field. The detection levels are often greater than levels that are of concern from a long-term exposure perspective, and thus the usefulness of these techniques is limited to situations where there is a desire to know if very large short-term concentrations are present at a site.

Refined monitoring techniques most often provide high-quality data at low detection levels (typically ppb range for gaseous contaminants) through whole air collection in bags or stainless steel canisters, or solid-adsorbent collection followed by detailed laboratory analysis with turn-around time measured in days to weeks. Refined screening techniques, such as field portable GC analyzers or field laboratories, offer an approach in-between screening and refined, but generally cannot provide the rigorous QA/QC procedures or the degree of speciation available from a certified off-site laboratory. A developing technology that does not require sampling is the use of long path optical absorption techniques that use radiation in the infrared or ultraviolet spectral regions and an interferometer to obtain absorption spectra that can be interpreted to identify and quantify the presence of trace gases.

The choice of sophistication level depends very much on what levels of detection will provide the site manager with meaningful information, and on what lead time is acceptable. Baseline assessments, for example, can often wait for detailed laboratory analyses; on the other hand, air concentrations monitoring during remediation need to be known in real-time so that decisions on site activities can be made with full knowledge of air concentrations.

Step 3 - Develop APA Plan

An APA plan for a modeling exercise should be documented in a protocol that describes how the analysis will be carried out. The protocol should document what sources are to be modeled and how emissions will be calculated. Source characterization, including sizes and initial dispersion for area and volumetric sources and stack parameters for point sources, should be specified. Other important topics for the protocol are selection of meteorological data, specification of a receptor grid, choice of model and a detailed list of model options, and determination of background concentrations. Preparation of a protocol is often overlooked, but the lack of a protocol can lead to re-doing an analysis if important details are not considered.

A monitoring APA plan includes several elements. Monitoring constituents should be selected based on several factors, including the physical and chemical properties of the pollutants, their toxicity and health effects, the availability of monitoring techniques, and concentration standards. The monitoring network design must be specified, including the number of sampling sites, their location, the number of samples to be taken, and the duration of the sampling effort. Meteorological monitoring should be included in the plan, to provide at least for measurement of wind speed and direction and sigma theta (standard deviation of the wind direction, an indicator of atmospheric turbulence). Additional parameters that should be considered are temperature, temperature gradient, solar radiation and/or net radiation, and precipitation. Finally, the monitoring plan should be documented in a QAPP.

Step 4 - Conduct APA

This step involves carrying out the selected APA through modeling or monitoring or a combination of the two. Important elements of this step include ensuring that qualified personnel are conducting the APA, that all QA/QC elements of the monitoring plan are being followed, and providing for meaningful reporting and display of APA results. Modeling results can be used to generate isopleths of concentration around a site. Superimposing the isopleths on a site map is an extremely useful way to present results.

Step 5 - Summarize and Evaluate Results

Monitored and/or modeled concentrations that are the end result of an APA need to be evaluated to determine if applicable standards are met (or will be met, in the case of projecting future concentrations). Data outputs from APA should be evaluated to make this determination. If the APA is being conducted during site remediation, turn-around time is critical so that decisions can be made immediately on whether to stop or modify cleanup activities. The basic decisions that need to be made as the result of an APA are as follows: 1) To control a source further or modify an activity to reduce air emissions, 2) To reject or modify a proposed remedial alternative based on its projected impacts, or 3) To refine the APA by obtaining more accurate emissions estimates or representative meteorological data, or utilizing a more refined model.

SECTION 6
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